POWER PLANT ENGINEERING

Established Over 31 Years

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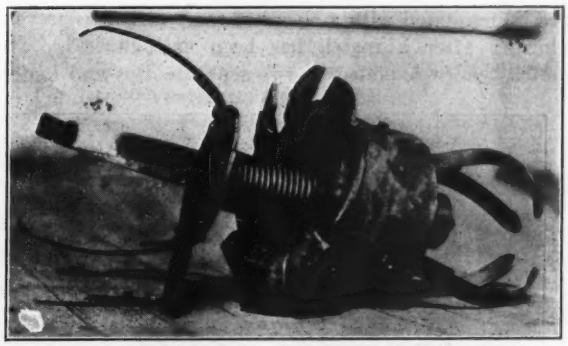

Diabolus Penetrabilis

THIS, GENTLEMEN, is the name of the strange creature shown above, a new form of crustacean recently brought to light in the neighborhood of Wisconsin Rapids, Wis. Of course, in order to be very scientific, it is necessary to give this new creature a Latin name (at least we hope it's Latin). Translating, however, we find that the name means "The Devil That Goes Through" or "Go-Devil." And here's how he got it.

Through a 10-in. pipe line about four miles long, The Consolidated Water Power & Paper Co. pumps sulphite pulp from the slush tanks of its mills at Wisconsin Rapids to the slush tanks of its mills at Biron. As reported by Consolidated News, the magazine of this company, this in itself is no mean accomplishment. There was a tendency for a slimy, jelly-like fungus to grow on the inside of this pipe, often breaking off and causing discoloration of the pulp. Chemical treatment did not prove satisfactory. Accordingly, T. R. Hayton of Appleton, Wis., was called on to solve the problem and his work resulted in the discovery of *Diabolus Penetrabilis*, or the "Go-Devil." He is about 24 in. long and is equipped with a row of hardened steel scrapers or blades, shown at the center. These are pitched somewhat like propeller blades and when he is placed in the pipe, into which he just fits, the motion of the liquid through these blades rotates them. In this process the blades scrape the jelly-like fungus off the walls of the pipe and *Diabolus* moves forward through the pipe at a speed of about 200 ft. a minute.

Steel tentacles or guides at front and rear keep him in perfect alinement and he never fails to negotiate the sharpest bends and finally to climb up a 20-ft. vertical run of pipe at the Biron end. It is reported that already scientists and biologists are flocking to Wisconsin to study *Diabolus* in his native habitat.

Ohio Match Company Makes Its Own Climate*

CONTINUOUS OPERATION OF MATCH MAKING MACHINERY AT WADSWORTH, OHIO, PLANT, WITHOUT REGARD TO OUTSIDE ATMOSPHERIC CONDITIONS, WAS MADE POSSIBLE BY INSTALLATION OF AIR-CONDITIONING EQUIPMENT. BY THOMAS CHESTER†

MATCHES ARE MADE nowadays by automatic machines, to which are fed small blocks of best quality white pine wood. The sticks or splints are cut from the blocks by rapidly moving dies and delivered to perforated plates, into which they are forced by the cutting heads. Each machine carries an endless chain of these plates, taking the wooden splints through a sequence of operations. After being immersed in hot paraffin they are impregnated with a chemical composition to prevent glowing after a match has been extinguished. The match heads are added by two separate dips and undergo separate drying processes, one after each dip. One match machine holds about 600,000 matches at one time and is capable of turning out approximately six million matches a day. Although one match head gives off little moisture, the total effect of millions drying at one time is very great.

The manufacture of matches began in this country in 1836, but until recent years it was necessary to shut down plants entirely during summer, and in spring and autumn whenever the wet bulb temperature reached a certain point, work had to be much slowed down or terminated until the following morning. This state of affairs had a bad effect on production and naturally raised operating costs. In addition more matches had to be made in cold weather, which meant locked up capital, expense of storage and increased fire risk.

In 1916, one of the largest concerns in the business, The Ohio Match Co., Wadsworth, Ohio, decided to make an attempt to get away from dependence upon fluctuating weather conditions and to make its own climate. The American Blower Co., for which the writer was at that time chief engineer, was called in and designed an air conditioning system for a building having about 980,000 cu. ft. of space and containing 24 match machines. A plant was installed capable of supplying 83,000 cu. ft. of air a minute, to maintain a room temperature of 72 deg. F., with a relative humidity of 50 per cent, allowing for a pick up of approximately 1.2 grains of moisture per cubic foot of air. In order to accomplish this, the air had to be made to leave the dehumidifier in a saturated condition of 42 deg. It was then passed through a reheater and, under thermostatic control, raised to a suitable temperature to maintain 72 deg. in the match machine room. The thermostatic control caused the air to leave the reheater below the room temperature in summer and above it in winter, to compensate for inward and outward radiation of heat.

In addition to the inward radiation of heat in sum-

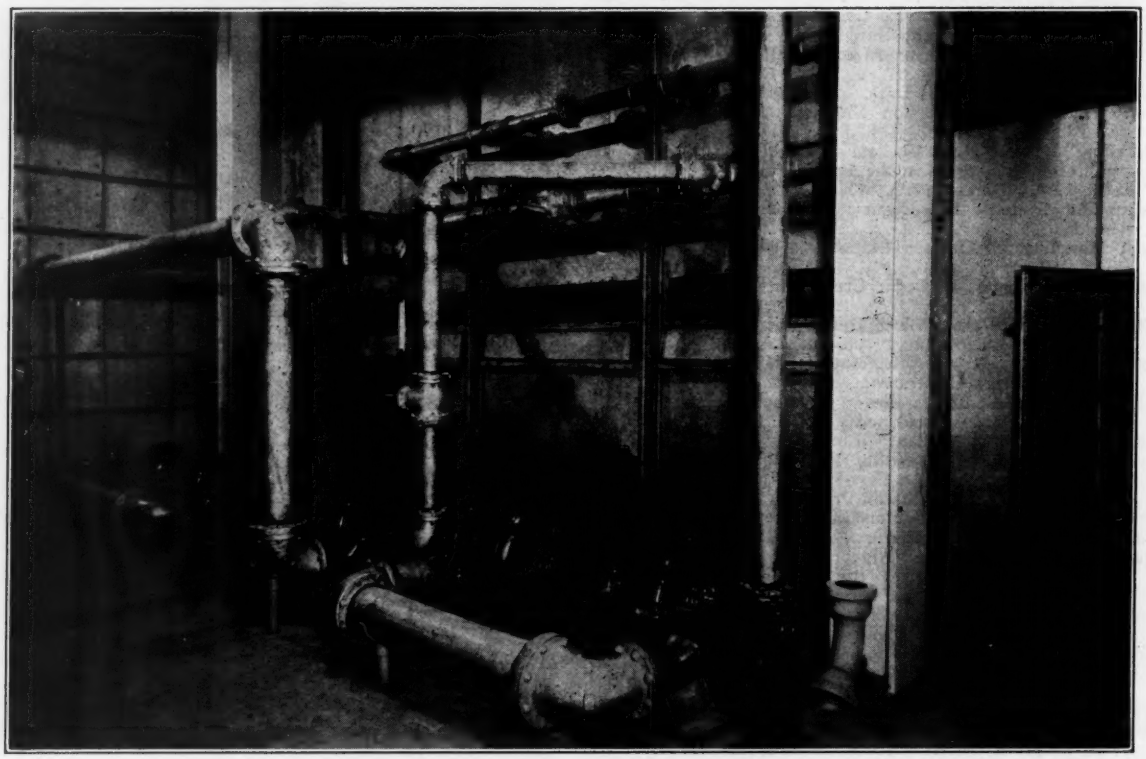

FIG. 1. SIDE VIEW OF DEHUMIDIFIER, SHOWING PUMPS THAT SUPPLY SPRAYHEADS. DOORS IN DEHUMIDIFIER CASING OPENED TO SHOW DISTRIBUTING TROUGHS

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†Engineer and contractor, Pittsburgh, Pa.

mer, figured in the usual manner for roof, walls and glass surfaces, heat was dissipated into the room from 150 operatives, each giving off 6 B.t.u. a minute, by electric motors totaling 360 hp., producing 42.5 B.t.u. a minute per hp., plus radiation from steam jacketed tanks containing melted paraffin and from steam pipes, the latter, however, being insulated.

It should be noted that in drying matches or other articles, the air temperature is lowered due to heat becoming latent in changing the evaporated water from a liquid to a vapor. Under the atmospheric conditions maintained at this plant, the evaporation of one grain of water by one cubic foot of air lowers the air temperature about 8 deg. F. This cooling effect is taken care of by allowing for it in designing the air heater, plus the allowance for loss by outward radiation in winter. Having installed a large enough air heater, the room thermostat regulates the supply of steam to it in such a way as to maintain the predetermined room temperature.

To meet these conditions equipment was installed as listed below. A No. 14 American Sirocco fan, operating at 170 r.p.m., belt driven from a 35-hp. motor, was put in and a special dehumidifier 22 ft. wide by 16 ft. 3 in. high by 12 ft. long in the direction of air flow. This dehumidifier is two tiers high, the upper chamber being the actual dehumidifier and containing the sprayheads, while the lower chamber encloses the Baudelot ammonia expansion coils. A Vento reheater containing 6372 sq. ft. of heating surface was installed. Two York Mfg. Co. refrigerating machines, each having two 16-in. by 24-in. vertical single acting ammonia gas compression pumps were installed, each being driven by a horizontal Corliss engine. This equipment comprises four gas compression cylinders and two steam cylinders. One double-pipe flooded type ammonia condenser consisting of 12 stands of 2-in. and 3-in. pipes, each stand or coil being 8 pipes high by 18 ft. long; one set of Baudelot water cooling coils, comprising 30 coils 12 pipes high by 10 ft. long, made of 2-in. full-weight steel pipe, galvanized on outside only, with sprinkling troughs, splash strips and ammonia headers; and one ammonia receiver 30 in. in diameter by 8 ft. long were installed. One oil separator 16 in. in diameter by 48 in. long, one ammonia accumulator 36 in. diameter by 8 ft. high, containing a coil comprising 282 lineal ft. of extra heavy 2-in. steel pipe, and two Allis-Chalmers centrifugal pumps, each for 1200 gal. per min., 60 ft. head, motor driven, completed the equipment.

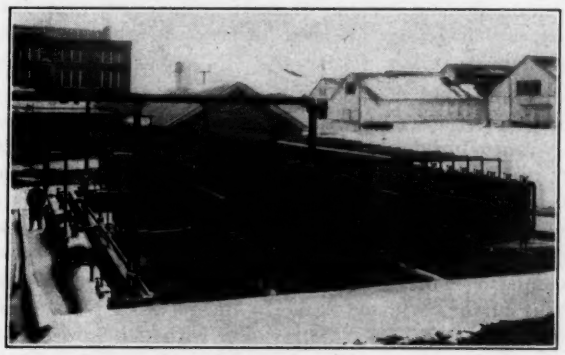


FIG. 2. ATMOSPHERIC CONDENSERS SERVE BOTH OLD AND NEW DEHUMIDIFYING PLANTS

FIG. 3. SUPPLY DUCTS RUN UP TO FACTORY BUILDING THROUGH VERTICAL BRICK FLUE SHOWN IN FIG. 8

The function of the ammonia accumulator is to utilize the low temperature of the ammonia gas leaving the Baudelot cooling coils, enroute to the gas compression pumps, for precooling the liquid ammonia before it passes through the expansion valves to the interiors of the Baudelot coils. This improves the operating economy. The water supplied to the condensers, for liquefying the compressed ammonia gas, is not much below 60 deg. F., whereas the off-going ammonia gas from the Baudelot coils is below freezing point, the exact temperature being dependent upon the suction pressure.

From a series of tests the average operating conditions in summer were found to be as follows:

Room condition	72 deg. dry bulb, 60 deg. wet bulb
Relative humidity	50 per cent
Steam pressure	129.5 lb.
Ammonia suction pressure	32.2 lb.
Ammonia discharge pressure	205.0 lb.
Water to ammonia condenser	56.5 deg. F.
Water off ammonia condenser	76.0 deg. F.
Water from dehumidifier to Baudelot coils	40.2 deg. F.
Water off Baudelot coils	34.2 deg. F.
Ammonia suction temperature	20.8 deg. F.
Ammonia discharge temperature	242.2 deg. F.
Speed of ammonia compressors	76.0 r.p.m.

In its course through the match manufacturing room, the conditioned air diffuses with water vapor produced at the rate of about 95,000 grains a minute; this includes the inward infiltration of a certain amount of air carrying higher humidity from the outside atmosphere. The air is made to travel in a closed circuit and upon commencing each cycle passes through the dehumidifier, where it is chilled and its moisture content lowered from 4.4 to 3.2 grains per cubic foot. A fractional amount of fresh air from the outside is taken in ahead of the dehumidifier to keep up the standard of atmospheric purity in the match machine room.

Water used in the dehumidifier moves in a closed circuit. After being chilled as it falls by gravity over the Baudelot cooling coils, which contain ammonia changing from a liquid to a gas, the water is drawn from a large horizontal rectangular tank at the floor line by

FIG. 4. ONE OF THE COMPARTMENTS IN UPPER CHAMBER OF DEHUMIDIFIER, SHOWING SPRAYHEADS

centrifugal pumps and delivered under pressure to the sprayheads in the superimposed air washing chamber. After passing through the air, the spray falls into an upper tank and again commences its circuit by cascading down over the Baudelot coils.

Ammonia, too, travels in a closed circuit. During each cycle it changes from a highly compressed hot gas to a cool liquid, passes through the expansion valves and changes within the Baudelot coils to a gas at about 20 deg. F. The latent heat required for this latter change is taken from the water in the dehumidifier, and in turn from the air and water vapor. All the heat taken from these sources is, of course, finally delivered to the cooling water used in connection with the ammonia condensers. In some instances atmospheric cooling towers are used for cooling the water used by the ammonia condensers and in such cases the heat taken from the air in the factory is delivered to the warmer outside atmosphere. In this particular installation cold well water is used for cooling the ammonia condensers, as this practice results in reduced power consumption.

Economic benefits resulting from the use of this apparatus, which rendered it possible to operate 24 match machines at full speed all the year round, under constantly maintained atmospheric conditions, caused

FIG. 5. SELF-FLUSHING AUTOMATIC SPRAYHEAD USED IN THIS APPARATUS

the directors of The Ohio Match Co. to decide to equip similarly another building containing 24 machines. This portion of the factory was shut down during the summer of 1924 while the dehumidifying plant was being installed.

It was also decided to reduce the relative humidity in the drying zone below 50 per cent. The new apparatus was designed to maintain a wet bulb temperature in the match machine room of 60 deg. and as high a dry bulb temperature as could be obtained at reasonable cost, the differential of course being the index of the relative humidity.

The section of wet and dry bulb recorder chart reproduced herewith shows what was accomplished in this respect. With this new equipment the wet bulb temperature is maintained at about 60 deg. F. and the dry bulb temperature around 78 deg. This represents a relative humidity of 33 per cent and a dewpoint of 46 deg. Under these conditions very satisfactory drying can be accomplished. This was achieved principally by circulating a greater volume of air and by causing it to leave the dehumidifier at a considerably lower temperature than was possible with the first installation. This new air conditioning equipment reduced the time required for drying, thereby rendering it possible to manufacture more matches per machine per hour. The writer was retained as consulting engineer and with the co-operation of O. E. Swartz, director and superintendent of The Ohio Match Co., designed and supervised the construction of the new plant.

Additional refrigerating apparatus was installed and for convenience of operation this was erected alongside the existing equipment. Two York refrigerating machines were purchased, each having two 16-in. by 20-in., vertical single-acting ammonia compression cylinders, and each being driven by an Ideal Electric & Mfg. Co., 275-hp. synchronous motor, operating at 150 r.p.m. This considerable load enabled an attractive saving to be made in the cost of power. Old and new machines were cross connected to enable any part of the entire equipment to be operated as desired. An item of interest in this arrangement is that one of the steam driven compressors can be used for pumping out the lines and placing the liquid ammonia in the storage tanks. Because of steam operation, the compressor used for this purpose can be run at very low speed, which is of advantage in this performance.

The old double pipe ammonia condensers were replaced by a complete new battery of the atmospheric type, made of 2-in. extra heavy pipes, the coils being 12 pipes high and about 20 ft. long, as shown by Fig. 2. This condenser provides enough cooling surface for the old and new dehumidifying plants. With the atmospheric type of condenser it is an easy matter to remove scum and dirt from the pipe surfaces and thereby maintain the condensing efficiency. A greater amount of cooling surface per ton of refrigeration was provided, thereby lowering the head pressure to about 185 lb. per square inch.

Connecting the apparatus room with the sixth floor of the factory, a vertical brick flue, Fig. 8, encloses a galvanized iron return air duct with a cross section of 20 ft. by 8 ft., and within this return duct two vertical supply ducts, each 6 ft. 3 in. diameter. Figure 3 is a photograph taken within the apparatus room at the base of the vertical brick flue and, through the open louvre damper can be seen the nearer of the two supply ducts. This picture was taken inside the return air chamber, which, it will be noted, is lined with galvanized iron paneling inside the walls and ceiling to prevent infiltration of humid air from the outside atmosphere.

Figure 1, also taken within the return air chamber, shows the dehumidifier and motor-driven centrifugal

pumps. The dehumidifier is 32 ft. wide by 16 ft. high by 22 ft. long in the direction of air flow. The lower compartment contains 60 stands of 2-in. galvanized Baudelot water coolers, each 14 pipes high by 10 ft. long. These coils are erected 30 coils on each side of a central aisle to provide easy accessibility for inspection and repairs. The sides of the lower compartment consist of removable panels for the same reason. Each of the three side panels contains an opening 6 ft. 3 in. long by 12 in. high, through which the distributing troughs over the Baudelot coils can be withdrawn horizontally for cleaning. In the photograph, which shows a side view of the dehumidifier, three of these horizontal openings will be noted, the hinged doors normally covering them having been dropped to show the ends of the distributing troughs. Three centrifugal pumps are provided, two being for supplying water to the sprayheads under normal operating conditions; the third pump, at the right, is used occasionally for flushing out the nozzles, which are grouped in units for this purpose by suitable pipes and gate valves to permit flushing one unit at a time without using any great amount of high pressure water.

This is a two-stage dehumidifier. The pump at the left takes the cold water, at approximately freezing point, from the lower tank and delivers this water to the last 50 per cent of the sprayheads in the direction of air flow. The upper tank has a vertical partition at its center, running from side to side. The coldest spray water falls into the back half tank, goes to the second pump and is delivered to the first 50 per cent of the sprayheads where the air enters the dehumidifiers. This water then falls into the front half tank and thence to the distributing troughs over the Baudelot cooling coils in the lower compartment. Because of this two stage arrangement it is possible to reduce the leaving air temperature to about 34 deg., which lowers the moisture content to about 2.3 grains per cubic foot.

The upper chamber is divided into four compartments, each having two sets of sprayheads. The number of heads used in each compartment is equal to one normal row but they are set staggered to improve the

FIG. 6. ENTERING END OF DEHUMIDIFIER; CONCRETE PIERS AT RIGHT SUPPORT TEMPERING COILS AT FRESH AIR INLET

operating efficiency. Each compartment is provided with a walkway of galvanized Subway grating. Narrow eliminators are placed between each two compartments. Figure 4 shows one of these compartments; the direction of air flow is across the picture from right to left.

Figure 5 shows one of the 400 self-flushing automatic sprayheads used in this dehumidifier. At the extreme right is a knurled locknut used to lock the deflector head in position required for any particular spray density. Immediately at the left of the locknut is the deflector head which has an anticlastic diffusing surface. The locknut and the deflector head are threaded on a central stem which also carries a three-winged centralizing member and a helical spring. In operation the deflector head is just clear of its seat and is in equilibrium between the outward thrust of the water and the inward pull of the spring. When high pressure water is turned on, the spring pull is overcome which greatly increases the orifice and the rush of high pressure water cleans out the nozzle. When the normal water supply is again turned on, the deflector head returns exactly to its former position.

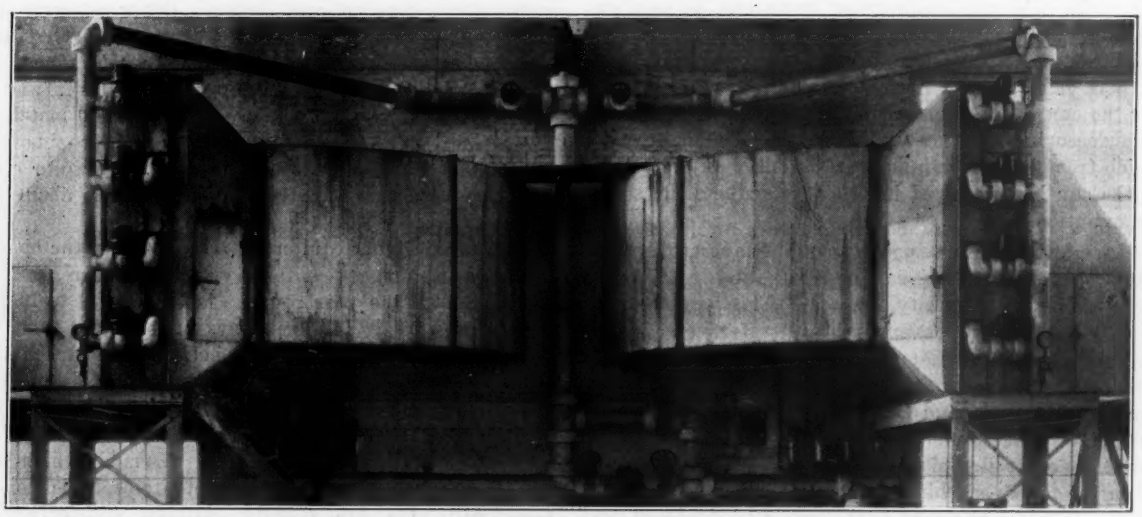


FIG. 7. SUPPLY DUCTS DELIVER REFRIGERATED AIR TO HEATERS CONTROLLED BY THERMOSTATS

Figure 6 shows the front or entering end of the dehumidifier. The large pipe extending from the central aisle of the lower compartment conveys the expanded ammonia gas back to the compression cylinders. The upper compartment in which the sprayheads are located is provided with a set of narrow eliminators to straighten out the entering air and prevent the formation of eddies. At the right of this picture is the fresh air inlet, provided with Vento tempering coils carried on concrete piers. During summer operation this fresh air inlet is almost entirely closed.

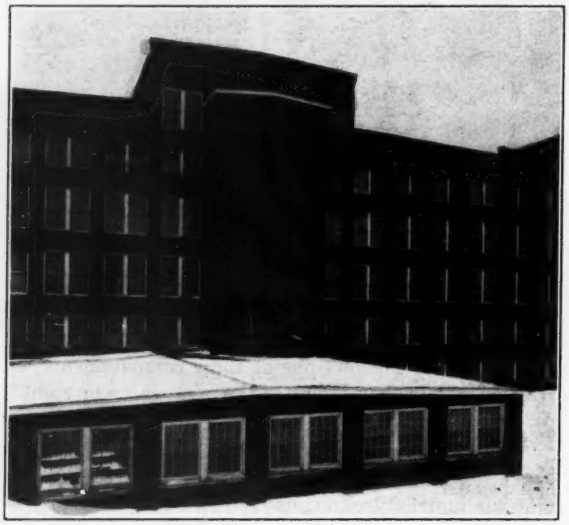


FIG. 8. SUPPLY AND RETURN DUCTS GO FROM APPARATUS ROOM TO SIXTH FLOOR OF FACTORY THROUGH BRICK FLUE SHOWN HERE

At the top of the large vertical brick flue, the two 6 ft. 3 in. diameter galvanized ducts are transformed into rectangular shapes and pass through the end wall of the building. Figure 7 was taken within the building on the sixth floor, looking toward the inside of the end wall. The two rectangular ducts can be seen extending to left and right, permitting delivery of the refrigerated air to Aerofin heaters equipped with diaphragm valves, which regulate the supply of steam under the control of two thermostats located in the match manufacturing room on the fifth floor. The main ducts which traverse the sixth floor are intentionally left bare, as the sun heat received in this way reduces the steam consumption.

In addition to having dry bulb temperature thermostat control, the original plant supplied in 1916 was equipped with humidity control. This operated by modifying the temperature of the water sent to the sprayheads, by providing a suitable mixture of water from the coldest source namely the lower tank beneath the Baudelot coils, and the slightly warmer water from the upper tank, under the influence of a hair member humidity controller placed in the path of the return air from the match machine room. As will be understood, more cold water was used as the humidity increased, and a greater portion of water from the slightly warmer source was made use of as the relative humidity of the room atmosphere decreased.

The new plant operates under dry bulb control alone. It is obvious that the water from the Baudelot coils can never get below 32 deg. Furthermore the wet bulb temperature remains uniform at all parts of a room in which water is being evaporated on any considerable scale. If any of the match machines are shut down this reduces the supply of heat to the spray water and is indicated by lower suction pressure gage readings; this permits the compressors to be operated at lower speeds. Under actual operating conditions, however, it is customary for all 24 match machines to be working at the same time.

Resulting from the experience gained in the operation of these plants, the original equipment erected in 1916 was provided with more ammonia condenser coils and also with additional Baudelot water cooling coils. This enabled the head pressure to be lowered and the suction pressure increased, which increased the refrigeration capacity. During 1925 the air distributing system of the original dehumidifying system was entirely redesigned, to conform to the arrangement followed in the newer plant.

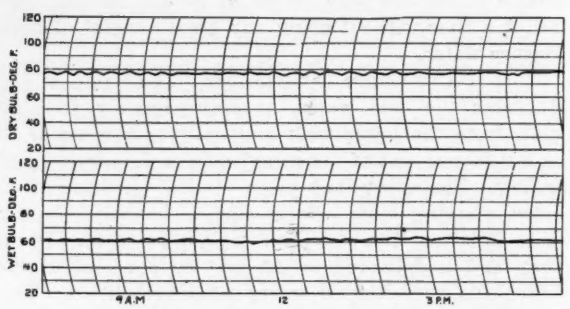


FIG. 9. CHART SHOWING HOW EVENLY WET AND DRY BULB TEMPERATURES WERE MAINTAINED

This factory manufactures what are known as the American double-dip strike-anywhere safety matches. These are sometimes referred to as parlor matches. They are quite different from the small safety matches imported from Sweden and Japan. Other concerns in this country also make the double-dip match. They are made from the best straight-grained white pine. A tree 150 yr. old, having a height of about 150 ft. and a diameter of about 3 ft., will produce 6,000,000 matches. The capacity of this particular factory is approximately 350,000,000 matches a day. The total per capita consumption of matches in the United States is about 25 a day.

Air conditioning equipment is essential to the operation of a modern match factory which is to remain in production all the year round. If too high a temperature is used in drying, small gas bubbles will form in the match heads. When such matches are struck the small pockets of gas expand instantaneously, due to the great increase in temperature. A match of this kind will act as a small bomb and project flaming pieces of its head to considerable distances. A match which has been properly made under correct atmospheric conditions will take fire silently, without sputtering or exploding.

Opposed Blast Promotes Good Combustion

Using Equipment Designed to Insure Proper Feeding and Mixing of Powdered Coal and Combustion Air, an Industrial Furnace Has Heat Liberation of 63,800 B.t.u. per Cubic Foot. By S. C. Martin

IF PROPERLY APPLIED in connection with the firing of powdered coal, use of the opposed blast of air should produce intense combustion and an extremely rapid rate of heat liberation per cubic foot of combustion space. A solid fuel, such as coal, containing volatile matter, is separated by the heat before ignition into a gaseous and a solid constituent, each of which requires different conditions of air supply to burn it most efficiently.

Pulverized coal is not similar to oil or gas. It leaves the burner and enters the furnace as a cloud of fine solid particles, mixed more or less intimately with different proportions of air, the degree of fineness of the individual particles of fuel varying to a considerable extent as well as their contour. These particles, after part of their volatile content has been distilled off, are ignited and complete their combustion while suspended in air. In this air may be present, in varying proportions, inert gases resulting from previous combustion as well as gases that are still burning. Moreover, the solid particles may be entirely enveloped in ash before their combustion is complete.

The problem of meeting the requirements for most efficient burning of powdered coal under the conditions which generally prevail in the pulverized-fuel-fired-furnace is difficult in many respects, because accurate control can not be had over all the factors entering into the combustion process.

Control of Combustion with Grates and Powdered Coal

When coal is fired on grates, the gases collect and form a layer above the bed of heated fuel and air can be mixed with them there independently of the solid content. There is also a layer of pure air in contact with the bed of coal flowing from below up through the interstices and along the glowing surfaces of the lumps of fuel and driving the gases ahead of it. In addition, the ash which collects in proximity to the burning coal can be eliminated by mechanical means.

With powdered coal, on the other hand, there is in some parts of the furnace a tangled mass, so to speak, of hydrocarbon gases both unburned and burning, also inert gaseous products of combustion, ash, air and solid particles of coke, the latter in process of burning with various degrees of intensity. Such a condition may be referred to as turbulent, and to get some orderly method of burning out of this chaos would seem impossible.

With nearly all methods of firing powdered coal, however, we can mix air intimately with the combustible gases, as they are distilled from the fuel previous to their ignition, with much better success than we can when coal is fired on grates. We can also control, to a certain extent, the general direction of the air and gases and the solid particles of fuel for a considerable distance beyond the mouth of the burner. And without much difficulty we can obtain a fairly rapid rate of combustion.

The gaseous content of the fuel, having a sufficient amount of air mixed with it, will burn at any place in the combustion chamber with equal intensity after it has ignited, provided the mixture does not become cooled or diffused with inert gas. Not so the solid particles of coke, which must depend upon the velocity of their air supply for intense combustion.

While the method of admitting all of the required combustion air to the furnace mixed with the entering fuel often results in nearly perfect combustion and very high furnace efficiency, as numerous tests have shown, yet flame speed in the gases can not be the highest unless the air mixed with these gases is in proper proportion for maximum flame speed. This proportion is not that which generally obtains when all of the combustion air enters mixed with the fuel.

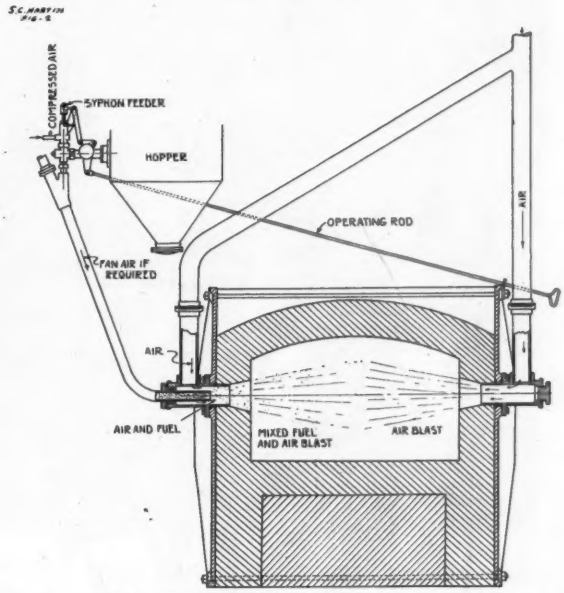


FIG. 1. SECTION THROUGH INDUSTRIAL FURNACE SHOWING BURNER AND TUYERE, WITH SIPHON VALVE AND AIR PIPES

With a lesser proportion of primary air, additional air (secondary air) must enter the furnace in some other manner to aid in the completion of combustion. If secondary air is admitted to the furnace through ports or openings in the furnace walls, there can be no definite control of its direction of travel after it enters the combustion chamber and it may act efficiently or inefficiently in aiding combustion.

Many systems of burning powdered coal give excellent results at low ratings, but at higher ratings, when two or three times the normal amount of fuel must be burned in the same length of time in the boiler setting, it is necessary to have either more rapid combustion or a large combustion space in order that the fuel may not pass into the tube space before it has burned completely.

Small furnace volume is desirable and if the rate of

burning of the fuel can be increased, the velocity of the air and the gases through the combustion chamber may be increased and the space necessary for the combustion of the fuel reduced.

The opposed blast of air should be applicable with advantage to boiler settings as a means of increasing the rate of combustion of powdered coal, thus allowing a reduction in the volume of the combustion chamber. With this method of burning there is not only rapid and intense heat evolution, but the locus of the zone of intense heat is defined to a certain extent and its position in the furnace subject to some degree of control. Excess air ports in the walls of the furnace should be unnecessary, for the opposing blast supplies air to the point where it can be utilized most effectively, while its entering velocity allows little time for it to become diffused with the furnace gases before it comes in contact with the ignited fuel. Moreover, its passage through the intensely heated furnace preheats it to some extent.

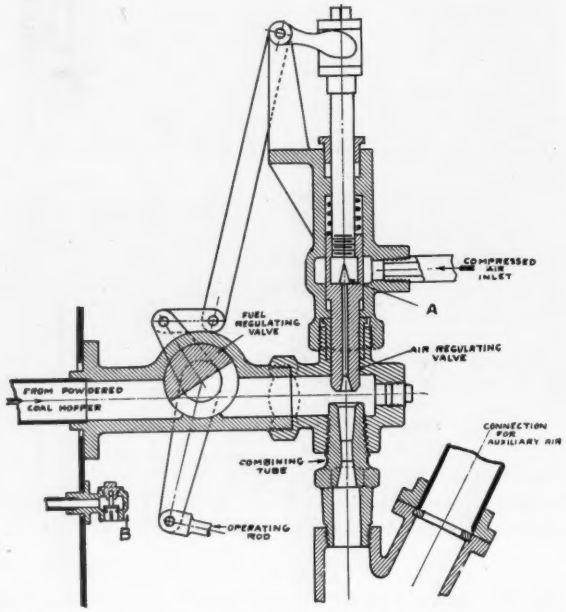


FIG. 2. CROSS-SECTION OF SIPHON VALVE, AIR AND COAL VALVES PARTLY OPENED. TRIANGULAR PORT A ADMITS SCAVENGING AIR TO CLEAR PIPES WHEN VALVES CLOSE

Inclining the tuyeres downward at an angle would project the ash toward the lower part of the furnace where it could be cooled by the water screen.

Method of Using the Opposed Blast with Powdered Coal

A patented method of utilizing the opposing blast of air in connection with the firing of powdered coal is now being used with forging and billet heating furnaces and has proved highly successful in this type of installation. This method should be distinguished from opposed blast systems in which both the opposing blasts consist of a mixture of powdered fuel and air.

Development of this method of burning was the result of an attempt to improve on an installation of powdered coal in connection with heating furnaces, the first application of which was made in an endeavor to find a suitable fuel to replace oil—a fuel which would be more economical while having the same ease of regulation and close control of temperature and which would result in a product equal in quality to that of the oil heated furnace.

The storage system for pulverized coal is used with this method of burning, the coal being first dried and then pulverized and stored in a bin, from which it is distributed by a circulating system to the various hoppers located near the individual heating furnaces. The storage system possesses the advantage of allowing a more accurate control of the relative amounts of fuel and air at the burner and of the air supply to the opposed blast. There is also the assurance of uniformity of moisture content and fineness of the powdered fuel, both of which are essential for most successful results when burning pulverized fuel in a small combustion space.

Figure 1 shows a cross section of a small heating furnace equipped with a tuyere and burner for operating with powdered coal using an opposed blast of air. The burner in this case consists of a 4-in. pipe fitting having a smaller pipe entering it and concentric with it. Primary air, supplied by a fan enters the annular space in the burner, the opposing blast taking its air from the same supply pipe at the same initial pressure.

A small quantity of carrying air under compression forces the powdered coal through the smaller pipe and on leaving the mouth this air expands, scattering the particles of fuel and mixing them intimately with the primary air flowing through the larger enclosing pipe. The mixture of fuel and air thus formed enters the furnace and, being immediately ignited by the intense heat, burns in contact with the opposing blast of air, the interior of the furnace presenting the appearance of transparent incandescence, no flame being visible.

Coal Transporting Device

To transport the powdered coal from the overhead hopper to the individual burners, a novel patented device is used, and is a necessary part of the equipment, insuring an even flow of coal which can be accurately controlled by a small movement of a hand lever. This device operates on the principle of the Giffard injector, compressed air at a moderate pressure being utilized to create a suction and cause the powdered coal to be drawn into the mixing tube and thence forced into the discharge pipe. Very little compressed air is required to siphon the coal from the hopper and carry it to the entrance of the discharge pipe, where its further transportation may be effected by lower pressure fan air if desired. Coal has been transported a distance of 200 ft. in this manner.

Construction of this part of the equipment is shown in the accompanying illustrations. Figure 2 shows the apparatus applied to a powdered coal hopper, with the coal and air valves partly opened, allowing compressed air to flow through the combining tube and coal to be drawn from the hopper. It will be noted that the coal and air valves are connected by levers and are operated in unison by the same handle.

An important part of the device is the small triangular opening at A in the upper part of the air valve. It will be seen that the upper part of this opening is

still in communication with the airchamber when the valve is seated and no powdered coal is flowing. A small quantity of compressed air is thus allowed to flow through the pipes after the coal supply has been shut off, thereby clearing them of all dust so that there is no liability of backfiring or explosion. The only wearing part of the siphon is the combining tube, a small screw machine part easily replaced. The small valve B, shown below the injector or syphon feeder, connected to a small pipe leading into the hopper, acts as a vacuum breaker by admitting air to the hopper to take the place of the coal which is being withdrawn.

FIG. 3. SIDE VIEW OF INDUSTRIAL FURNACE EQUIPPED WITH OPPOSED BLAST SYSTEM FOR BURNING POWDERED COAL SHOWN IN FIG. 1

TESTS SHOW HEAT LIBERATION OF 63,800 B.T.U. PER CUBIC FOOT

In a test run on a furnace equipped with this system of burning powdered coal, a high rate of combustion was obtained. Previous to making the run, the feed device or siphon was tested to capacity and found to be capable of feeding pulverized coal at the maximum rate of 666 lb. an hour. The furnace used in the test was an ordinary heating furnace similar to that shown in Figs. 1 and 2, the inside dimensions being 6 ft. by 6 ft. by 4 ft., equivalent to a volume of 144 cu. ft.

During the test the furnace door was closed and the feeder operated at full capacity, coal being burned at the rate of 666 lb. an hour. The heating value of the fuel was 13,800 B.t.u. and the rate of heat liberation was therefore 63,800 B.t.u. per cubic foot of combustion space per hour. As the feeder was unable to pass coal at a greater rate, the maximum amount of fuel that would burn in this combustion space could not be determined. This high rate of heat liberation was obtained with one burner supplying a mixture of powdered fuel and air, and one tuyere supplying air alone for the opposed blast.

As visualized originally, the blast serves the purpose of holding the particles of coal in suspension in a certain locus in the furnace and supplies pure air to them until they are consumed. In this respect the action may be compared to that of fuel spread out on a grate and having a blast of air directed against it. An additional advantage of the opposed blast is that the inert gases produced by the burning fuel tend to be driven outward away from the zone of intense combustion so that conditions within the zone are most favorable for the combination of oxygen with the fuel. Since the greatest heat is near the center of the combustion space and the flame is broken up, the furnace walls are protected to a great extent from the heat and the erosion of the flame.

LUBRICATION REQUIREMENTS for different types of service differ. One cannot assume that because an oil must have a certain characteristic for one class of service it must also have the same characteristic for another class of service. That oil for use in steam turbines will be satisfactory in proportion to resistance to emulsification with water has long been recognized. To manufacture an oil for use in steam turbines requires special care and skill so a non-emulsifying turbine oil commands a higher price than an oil that emulsifies easily. The assumption has often been made, however, that oils which resist emulsification are also better for other uses; for instance, are superior lubricants for automobile equipment, such as motor cars and trucks. This assumption, however, is not necessarily true, as shown by tests performed by the Bureau of Mines.

Coal Distillation Is an Economic Problem

TYPE OF COAL, DISTILLATION PROCESS, COST OF RAW MATERIAL, GEOGRAPHICAL LOCATION OF MARKET AND EFFECT OF LARGE PRODUCTION ON THE PRICE OF BY-PRODUCTS MUST BE CONSIDERED. BY W. RUNGE*

BRIEFLY the purpose of low temperature distillation is to remove from bituminous coal those ingredients which are smoke producing and which, when removed as by-products, have greater value as such than as fuel and, at the same time, produce a smokeless solid residue which is well suited for either domestic or industrial heating purposes.

Many claims have been made by investigators and promoters of the vast amount of revenue that it is possible to obtain by distilling coal at low temperatures.

TABLES I—III. REVENUE FROM THE DISTILLATION PROCESS DEPENDS LARGELY ON THE KIND OF COAL USED AND THE MARKET FOR BY-PRODUCTS

Table I

0.7 ton of semi-coke at $10	$7.00
4000 cu. ft. of 800-B.t.u. gas at $0.40 per M ft.	1.60
25 gal. of tar at $0.07	1.75
2½ gal. motor spirits at $0.19	0.47
Total	$10.82

Table II

Labor	$0.45
Repairs	0.25
Power and light	0.10
Lubrication, etc.	0.05
Fuel for carbonization	0.55
Light-oil refining	0.10
Total	$1.50

Table III

0.7 ton of semi-coke at $8	$5.60
4000 cu. ft. of gas at $0.40 per M ft.	1.60
25 gal. of tar at $0.05	1.25
2½ gal. of motor spirits at $0.15	0.37
Total	$8.82

It is true that a substantial and desirable profit is not only possible, but also probable but we must not let our fancy run wild with the expectation that each ton of coal treated by low temperature distillation is going to yield at least $10 or $15 profit per ton of coal distilled.

Many promoters in dealing with this subject go into the possible uses of a large number of so-called derivatives, citing, for example, the possibility of using the products from low-temperature tar in the preparation of dyestuffs, pharmaceutical preparations and many other chemicals, and set up opposite each an enormous value. As a matter of fact, little work has been done in these special fields with the compounds found in low-temperature tar, for they form an entirely different chemical group, and few of the derivatives can be used for dyestuffs. We must, therefore, limit ourselves in thinking of low-temperature carbonization to an average profit of $1 to $4 per ton, and in exceptional cases to a profit somewhat higher.

Probably one of the most common types of furnace that is used in low-temperature distillation is known as the rotary kiln. This type has been before the public eye for a number of years; usually it closely resembles the cement kiln in its general features, being about 8 to 10 ft. in diameter, 80 or 90 ft. long and slightly inclined off the horizontal. It is externally heated and its shell is usually of steel, about one-half to three-quarters of an inch thick. It is customary to feed the coal into the upper end of the retort and, due to the rotary motion and the inclination of the retort, discharge it at the lower end. Some investigators have improved upon this type of furnace by using two or three rotary furnaces in series, while a German process uses a retort consisting of an inner and an outer drum.

This retort is also externally heated, but it has the decided advantage that the entire weight of both drums and their contents is carried by the inner drum which, in this case, is the colder one. This drum is maintained at a temperature between 400 and 500 deg. F. or at the point at which steel has its greatest strength. The coal is fed into the inner drum and travels on a slight upgrade, being forced upward by vanes which act as a screw conveyor; having reached the top of its flight, the coal discharges into the outer drum and then, because of the rotary motion and the declination of the drum, flows downward to the feed end, where it discharges.

Then there is the stationary vertical type of retort arranged in batteries. These retorts in their general operation resemble a high-temperature by-product coke plant in that they are heated externally and are intermittently charged and discharged. Another type of retort is one brought out in the United States consisting of a horizontal stationary retort in which the coal is propelled through the retort by means of paddles. Another method is the carbonization of bituminous coal in dust form.

REVENUE OBTAINED DEPENDS UPON MANY FACTORS

It is impossible to discuss the revenue from a low-temperature distillation plant until the by-products obtainable are determined and this in turn depends upon the type of coal undergoing treatment. Another important factor is, of course, the cost of raw material, and the location of the plant. Personally the author feels that the best location is at a point where all of the products of the distillation may be readily disposed of.

From experience gathered in treating coal from many parts of the United States and other countries, it has been found that the heat content per pound of coke will average 700 to 1000 B.t.u. less than that of the coal from which it is made. This is a general rule for high volatile low oxygen coals. When dealing with the high oxygen coals it is quite often found that the heating value of the coal and the coke are about the same, or possibly that the coke is slightly higher. This is particularly true of lignite for in most cases there is an upgrading of the solid fuel and it is not rare to find a lignite whose calorific value is 2000 B.t.u. less than that of the char produced from it.

Gas, motor spirits, coke and semi-coke are some of the by-products. The gas produced is very rich and may be used effectively for enriching other gases. Pitch can be and is used as fuel, while most of the oil from

*International Combustion Engrg. Corp., New York. From a paper presented before the Kansas City A. S. M. E. Regional Meeting, April 4-6, 1927.

the distillation of tar must be utilized as wood preservative, disinfectant or flotation oils, although there are probably many special fields which will develop later.

It is doubtful whether a coal containing less than 25 per cent of volatile matter could be treated, because the yield of tar would be relatively small, whereas with coal containing 30 per cent or more of volatile matter, a very good yield of tar can be expected. Some experiments carried out a few years ago, in which the coal contained at least 30 per cent volatile matter, show the average yield of tar in the neighborhood of 27 gal. Some of these coals low in oxygen yielded as high as 31 and 32 gal.

Profit Will Probably Run From $2 to $4 per Ton

In summarizing the credit side of the operation for a plant carbonizing at least 500 t. of coal a day, the values of the various products have been reduced in order to present a more conservative estimate. From the $10.82 shown in Table I must be deducted $4.50 as the price per net ton of coal, leaving a balance of $6.32 to cover fixed charges, operating expense and profit. The operating charges other than fixed charges are shown in Table II and deducting this $1.50 from the previous balance leaves a remainder of $4.82 from which must still be deducted the fixed charges. These should not, except with an exceptionally expensive plant, exceed $1 a ton, leaving a final net profit of $3.82 per ton of coal treated.

In order to place the operation on a still more conservative basis, new credits which are considered extremely moderate are shown in Table III. Deducting the previous costs of $4.50 for coal, $1.50 for operating previous costs of $4.50 for coal, $1.50 for operating charges and $1 for fixed charges, leaves a net profit of $1.82 per ton of coal carbonized. It will be noted that the value of the semi-coke has been taken at $8, or approximately $1 per ton less than the cost of anthracite at the mine and it will further be noted that the price of tar has been reduced to 5c a gal. and the price of motor spirits to 15c per gal. All of the foregoing prices relate to those processes making a domestic product and producing it without resorting to briquetting.

Discussion Brings Out Value of Pulverized Coke

Features of the operation of the McEwen-Runge process as used at the Lakeside Station in Milwaukee were made public during the discussion of Dr. Runge's paper. The question arose regarding the ignition in the boiler furnaces of coke with the volatile taken out and it was stated that the same torch was used to ignite coke and coal and that the two fuels acted the same. Data on the rating possible to carry were not available but it was mentioned that in a six burner furnace burning coal, the ratings normally obtained were 650 per cent for six burners and about 60 per cent for three burners. When burning coke, a rating of about 100 per cent is obtained with three burners.

Coal being handled at the Lakeside plant is from western Pennsylvania, and the volatile varies from 30 to 35 per cent. It is dried and goes to the hoppers containing about 1.5 per cent moisture. The loss in volatile involved through the primary retort is about 1 per cent. Through the secondary retort the loss in volatile is a matter of operating condition and can be reduced to any point between 5 and 15 per cent. Samples of coke exhibited contained about 10 per cent volatile and experiments carried on with small funnels emphasized the free-running properties of the pulverized coke as compared with pulverized coal.

The 10 per cent volatile which remains after distillation will not yield tar and, if the process were carried further, as in a coke oven, where the volatile is reduced to 1 per cent or less, the gas obtained would be composed principally of hydrogen and nitrogen. If the volatile were reduced only to about 25 per cent, the coke formed would be difficult to handle as it would be quite plastic and tend to gum up the feeder at the bottom. Pulverized coke can be used as bunker fuel on ships or as locomotive fuel, as the tendency of pulverized coke in storage to spontaneous combustion is eliminated after the volatile has been removed.

Hydro-Electric Development in California

By Claude C. Brown

CALIFORNIA leads every state in the union in hydro-electric development, and leads the world in long distance transmission of high voltages, according to a survey just completed by the Gas and Electric Division of the California Railroad Commission.

California has 1,930,000 hp. already developed from her streams as against her nearest competitor, New York State, with a total of 1,757,355 hp. The figure for California includes public utility, municipal, irrigation district and government plants. If the private plants are not included in the New York state figure, a total for that state would be only 1,474,100 hp.

In line with her position as a leader in water power development, California still leads the world for the greatest length of transmission line and highest transmission voltages. One company in California transmits power over 500 mi. from its hydro plants as a matter of daily routine. Two companies use 220,000-v. transmission, the highest voltages so far used in the world, and experiments are being conducted with still higher voltages. The specially fitted laboratory at Stanford University, erected at great cost, can and does work with voltages as great as 2,000,000 v. in an effort to solve transmission problems involved in handling voltages exceeding 220,000.

The size of California hydro-electric plants, according to the tabulation, varies from the smallest plant of 9 hp. to 113,000 hp. for the largest plant. The greatest development on any one stream is that upon the San Joaquin River where a total of 440,000 hp. is now installed.

Following is a list of the principal hydro-electric generating plants and their capacity, and the total for all hydro-electric plants in California:

	Plant Capacity, Hp.
Southern California Edison Co.	467,000
Pacific Gas and Electric Co.	534,800
San Joaquin Light and Power Corp.	170,700
Great Western Power Co.	175,600
Southern Sierras Power Co.	93,500
California-Oregon Power Co.	78,400
Western States Gas & Electric Co.	35,700
Sub total	1,555,700
All other plants	374,300
Total all hydro-electric plants	1,930,000 hp.

Newspaper Plant Has Many Automatic Features

AMONG MANY OTHER THINGS, THE AUTOMATIC FIRE PROTECTION SYSTEM UNDER SUPERVISORY CONTROL IS AN INTERESTING FEATURE OF THE ELVERSON BLDG. PLANT IN PHILADELPHIA

NOTHING GETS STALE quicker than a newspaper. The late afternoon editions of a metropolitan daily issued at, say, 6 o'clock, are stale at 9 when the first editions of the morning papers begin to appear. Time, in the newspaper game, is an extremely important element, as a slight delay or interruption in the process of getting out an edition can incur the loss of thousands of dollars. A newspaper press, once started, must be kept running at its highest capacity until the edition

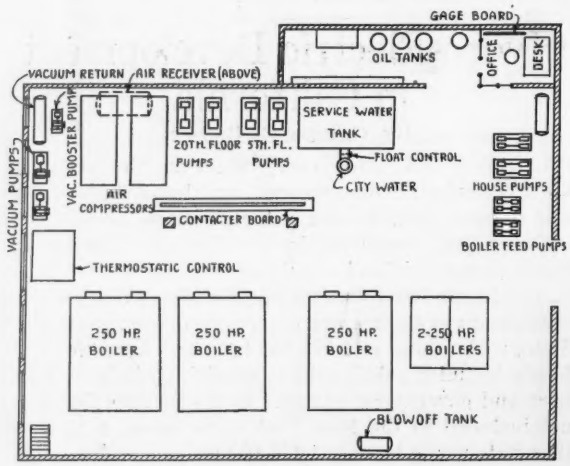


FIG. 1. PLAN SHOWING LOCATION OF EQUIPMENT IN THE BOILER ROOM

is off. It is very important, therefore, that in a newspaper office a continuity in the power supply be maintained.

That reliability of power service is a prime requisite in a newspaper plant is reflected in the many automatic features to be found in the new power plant of the Elverson Building, the home of "The Philadelphia Inquirer," in Philadelphia.

This plant consists essentially of a boiler plant and a converter room. No attempt is made to generate the electricity used in the building but, as practically all current used is direct current, a motor-generator installation is included, where 2300-v., 3-phase current is converted to 250-v. direct current.

In addition to the steam required for heating the building, a considerable amount of steam is needed for certain processes in the stereotyping department and for purposes throughout the building, so the boiler plant is more complete than might at first be expected.

Automatic Control Is Outstanding Feature

The outstanding feature which strikes the observer visiting this plant is the unusually complete provision of automatic control equipment on all important apparatus. Nearly every device is under automatic control—all the pumps are started and stopped automatically as the water level or pressure or temperature varies; all motors are accelerated through automatic contactors; the boilers are oil burning and need little attention; even the fire protection system is under complete automatic control. The latter system is of particular interest and will be described in detail later in this article.

Two Boiler Pressures Used

Two sets of boilers are installed, one low pressure set consisting of three 250-hp. Edge Moor units operating under about 15 lb. pressure for heating service, and another set consisting of two 250-hp. Harrisburg Star boilers for high pressure service. The latter usually operate at 110 lb. pressure, which is needed in the stereotyping rooms. The general arrangement of equipment in the boiler room is shown in Fig. 1.

Both sets of boilers are oil fired, using the Quinn system made by the Combustion Engineering Corp., one burner per boiler with steam for atomizing.

Two Warren 4½ by 2¾ by 4-in. pumps force the boiler feed water to the high pressure boilers. For the

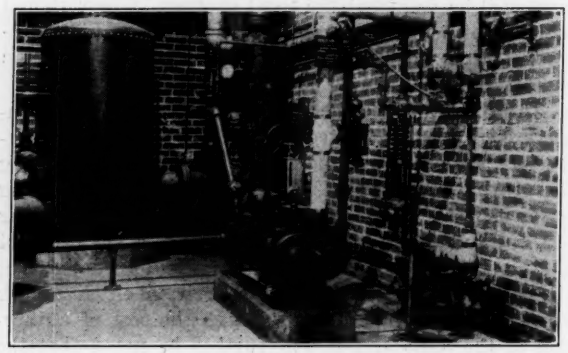


FIG. 2. VIEW IN THE FIRE PROTECTION ROOM, SHOWING THE SMALL STEAM PUMP IN FOREGROUND

low pressure units no feed pumps are provided. All returns from the heating system drain back directly into the boiler. Returns from the high pressure system are returned by means of traps into an Elliott Company open heater, which is supplied with exhaust steam from the boiler feed pumps, house pumps and oil pumps. The feed water temperature is maintained at from 170 to 200 deg. F. at all times.

For hot water service two Elliott hot water generators are provided. These heaters maintain the temperature at from 155 to 170 deg. These heaters serve to heat the water only to the fourth floor of the building. On the fifth floor two booster heaters again heat the water to a normal temperature of 155 deg. and it is then circulated to the 20th floor. If the booster heaters were not provided, the temperature of the water would drop to about 100 deg. These heaters are of the closed type, heated either by high pressure steam through reducing valves or by low pressure steam.

Circulation of the water in the system is effected by either of two Warren steam pumps, size 6 by 4 by 6 in. These pumps are operated alternately, being changed each month. As one pump is shut down, it is

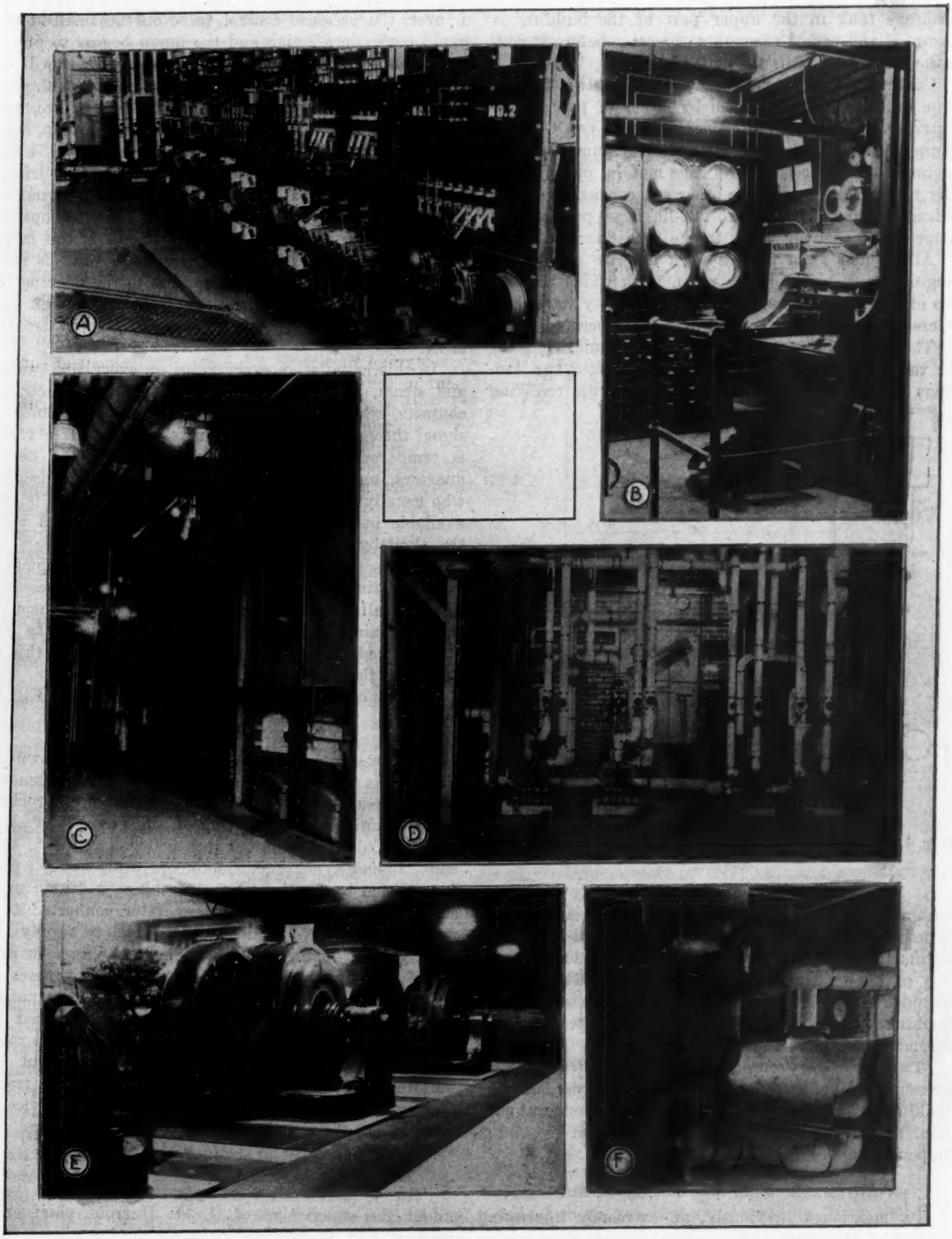


FIG. 3. RANDOM VIEWS IN THE ELVERSON BUILDING PLANT A. THE MAIN AUTOMATIC CONTROL BOARD IN THE BOILER ROOM. B. A CENTRAL GAGE BOARD IS INSTALLED IN THE ENGINEER'S OFFICE. C. THE BOILERS, SHOWING THE LOW PRESSURE UNITS IN THE FOREGROUND. THE HIGH PRESSURE UNITS ARE AT THE FAR END. D. THE PIPING ARRANGEMENT FOR THE BOILER FEED AND HOUSE PUMPS IS EXCEPTIONALLY WELL DESIGNED. E. A VIEW IN THE MOTOR-GENERATOR ROOM. F. THE DEAERATING HEATERS ON THE 5TH FLOOR

completely overhauled and repacked. Water stored in a storage tank in the upper part of the building is deaerated and passed through a separator before it goes to the main heaters in the boiler room.

Cold water for general purposes is drawn from a large tank in the boiler room by either of two sets of centrifugal pumps. One set, consisting of two Chicago Pump Co. 4-in., 500-g.p.m., 110-lb. head pumps, driven by Imperial Electric squirrel cage motors, pump water only to the fifth floor. The other set, consisting of two Chicago, 3-stage, 750-g.p.m., 220-lb. head pumps, also motor-driven, deliver water to the 20th floor.

All returns from process work are run into a rectangular tank in the boiler room, from which the two sets of centrifugal pumps take suction. City water also enters this tank under control of a float operated valve.

The heating system installed in the building is of the vacuum type for which there are installed two Jennings Hytor vacuum pumps, together with receiving

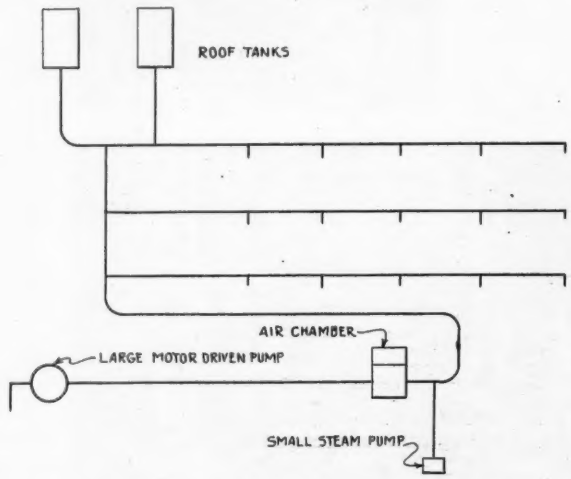


FIG. 4. SCHEMATIC DIAGRAM OF THE FIRE PROTECTION SYSTEM

tank and booster pump. The booster pump is used only to assist one of the main pumps in case of necessity; ordinarily, it is not used. A Johnson thermostatic system of temperature control is installed. This system includes two small motor-driven air compressors which maintain an air pressure of 40 lb. for operating the thermostatic valves in the building.

Two large air compressors supply air at 100 lb. pressure for general cleaning purposes throughout the building. These are Pennsylvania compressors with 9-in. air cylinders and 8-in. stroke, driven by 25-hp. Imperial 220-v. motors.

Automatic Fire Protection System

As mentioned previously, an extremely interesting feature of this plant is the Central Station Supervisory Sprinkler system installed. This is an entirely automatic system and is supervised from the central station of the Consolidated Fire Alarm Co. in Philadelphia. A simple diagram of the system is shown in Fig. 4.

Under normal conditions the sprinkler system is always filled with water at a pressure of 148 lb. If, for any reason, the pressure in the system should fall 7 lb. or over, the pressure control valve on the small steam pump comes into action and the pump begins to pump slowly and, if nothing unusual has occurred, it will in a few minutes bring the pressure back to normal. If, however, due to open sprinklers caused by a fire, the pressure, in spite of the efforts of the steam pump, continues to fall and the pressure finally drops to 134 lb., a relay is tripped which starts the large motor-driven pump. This relay at the same time sends a signal to the central headquarters of the fire alarm company, notifying them that the pump has started. If this large pump, which is a 1000-g.p.m. De Laval unit, is still unable to maintain the pressure, due to the opening of more sprinklers, and the pressure continues to fall another 7 lb., a general alarm is given to the fire department.

In this installation every valve on every line, water and steam, in the pump room is fitted with electrical contacts, which, when the valve is operated, sends a signal through relays to the central station. If a valve is tampered with without first notifying the headquarters, an investigator is sent down on motorcycle who usually arrives in about 10 min. If a man is not available immediately, headquarters get in touch with the plant by telephone.

If it is desired to work on any of the equipment, the repacking of a valve, for instance, it is necessary, first, to call the fire alarm station and notify them of the approximate time it will take. As soon as the job is completed, headquarters must be advised. If this is not done, they either call up or send a man.

A view of part of this equipment is shown in Fig. 2.

Converter Equipment

A view in the motor-generator room is shown in Fig. 3E, in which can be seen two of the motor-generators with a part of the third. These are Crocker-Wheeler units, each consisting of a 500-kw., 250-v., d.c. generator, direct connected to a 580-kv.a., 2300-v., 146-amp., 3-phase synchronous motor operating at 720 r.p.m. In addition to the three large machines, a fourth unit, consisting of a 150-kw., d.c. generator connected to a 225-kv.a. motor is installed and is used to supply the color presses during the day. These machines furnish all of the direct current used for power purposes in the building. Twenty-three hundred-volt alternating current for the motor-generator sets is furnished by three 13,500/2400-v. Pittsburgh transformers, each rated at 500 kv.a. For a.c. power service throughout the building, there are installed three 13,500/220-v. transformers, each rated at 200 kv.a. Lighting service is supplied by three 13,500/220—110-v. transformers.

Conclusion

This plant has been in operation for over a year, under the supervision of G. W. Harrold, chief engineer, and H. C. Wright, assistant chief engineer. All equipment is kept in A-1 condition by constant attention and by systematic overhaul.

Dry, dull or rusty bearing surfaces indicate insufficient lubrication and they should receive immediate attention.

Calculating Performance of Extraction Turbines

STEAM REQUIREMENTS FOR STAGE FEED-WATER HEATING BY STEAM EXTRACTED FROM THE MAIN UNIT CAN BE EASILY FOUND AND THE THERMAL EFFICIENCY OF THE CYCLE AND THE INCREASE IN THERMAL EFFICIENCY OVER THE NON-EXTRACION CYCLE DETERMINED. BY BRIAN M. THORNTON

PRACTICALLY all of the recent central stations, as well as many industrial power plants are heating the feed water by steam bled from the main turbine. A discussion of the various factors involved in the practice could not be covered in a single article and it is intended to present here only a simple and rapid method of calculating the performance of these extraction turbines.

In any method of calculation it is necessary to show the stage efficiency of the turbine in order that the condition curve or expansion line may be drawn on the Mollier diagram. For all calculations relating to bleeding, the easily drawn straight expansion line is fully accurate enough. It is not necessary to draw the more accurate curved expansion line, but the line should be located fairly close by taking heat drops for at least one or two points between the initial and final stage points. One per cent error in estimating the mean stage efficiency would result in only a small fraction of 1 per cent error in the gain due to bleeding. Tests of extraction turbines have shown that the quality of the steam is scarcely affected by bleeding and the expansion line may be drawn down as though the turbine were performing without bleeding.

From long established laws of thermodynamics, the gain due to bleeding has its source outside of the turbine and while the secondary effects, such as increased vacuum and decreased leaving losses, certainly increase the internal efficiency of the turbine, the total effect is small and can be neglected. In Fig. 1 the expansion line is drawn on a temperature-entropy diagram rather than the Mollier diagram to facilitate demonstration. In practice all calculations are based on the Mollier diagram as with the expansion line drawn down by methods described in any text book it is a simple matter to pick out the entropy of the steam at the pressures at which the steam is to be bled.

HEATERS FORM A READY METHOD OF DETERMINING THE TURBINE EXPANSION LINE

Before leaving the expansion line, it may be mentioned that bleeder heaters furnish a ready means of determining the actual expansion line of the turbine. The heater is a surface condenser and with a few simple measurements may be used as a calorimeter to determine the total heat of the steam at any point. If the pressure at the bleed point is also determined the corresponding point on the Mollier diagram is definitely fixed. In this way a check may be made on the designer's assumptions and actual values of stage efficiency, reheat factor and other fundamental data determined.

In fixing the pressures at which steam is to be bled, the only variable for a given design is the number of heaters to be used. The thermal gain increases with the number of heaters but considerations of space, weight and cost limit the number. In 19 power plants put in operation in America since 1923, the average number of heaters used is 2.8. As can be seen, the most financially economical number of heaters increases with the boiler pressure. The maximum temperature to which the feed water could be heated is the boiler water temperature and, with the usual cycle, employing highly superheated steam, this would necessitate bleeding high pressure steam in the superheat field with a slight loss in efficiency.

SUPERHEATED STEAM SOMETIMES USED FOR HEATING

It is usual to employ only the high pressure heater in the superheated field if this is done at all. When

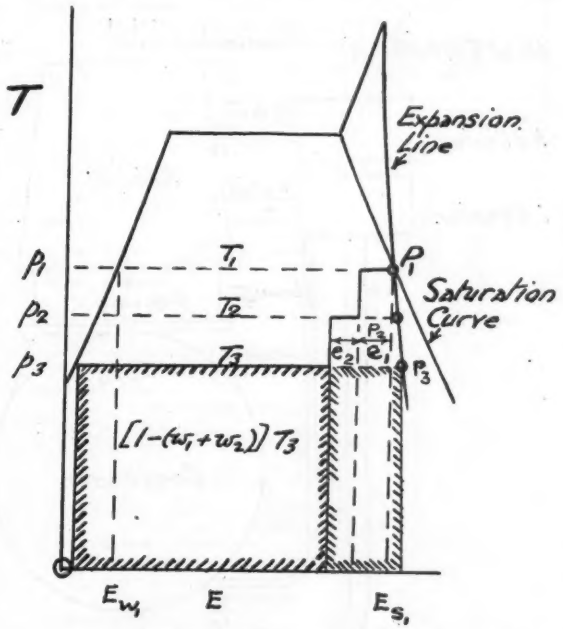


FIG. 1. EXTRACTING STEAM FOR FEED-WATER HEATING DECREASES THE AMOUNT OF HEAT REJECTED BY THE TURBINE

bleeding superheated steam, the common practice is to treat it as saturated steam for estimating the mean temperature difference and surface of the heater, but the weight of the steam to be bled must be calculated by taking the superheat into account and this is done automatically in the method described below. In the arrangement shown in Fig. 2 the feed water is heated to the temperature corresponding to the pressure at which the steam just becomes wet in the turbine. That is the intersection of the turbine expansion line and the saturated steam line on the Mollier diagram, point P in Fig. 1.

In the method given below, a two-heater cycle is considered. In modern practice it is usual to employ from two to five heaters, depending upon the station heat balance. The method can be extended in exactly the same manner as indicated for any number of heaters. A five-heater cycle would naturally take longer to solve than a two-cycle heater, although there is no difference in the method. It is sometimes necessary to determine the most economical final steam temperature as given in connection with a number of heaters. The solution of

this problem is obtained by applying the method indicated with various numbers of heaters with final feed temperatures. Plotting the curves of thermal efficiency against feed temperature for any one number of heaters will clearly show the point of maximum economy. At the same time the influence in a number of heaters of both the efficiency and the maximum economical steam temperature will be indicated. Both the efficiency and maximum feed temperature are increased with the number of heaters, though with more than four heaters, the increment of gain falls off rapidly.

In dividing the work between the heaters, it is usual to make the heaters do an approximately equal amount of work, slight preference being given to the low-pressure units. Extremely accurate spacing of heaters

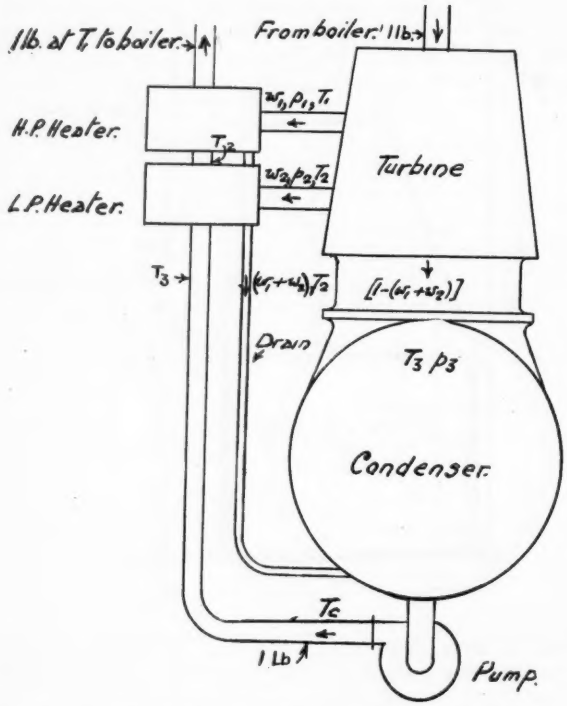


FIG. 2. DRAINS FROM THE HEATERS ARE CARRIED BACK TO THE CONDENSER

is, however, not important. In the calculation below, the assumption is made that perfect action takes place in the heaters. In practical calculation it is a simple matter to allow for the small terminal temperature difference at the high pressure heater. Knowing the temperature of the condensate and the upper feed water temperature, the heat required from the bled steam may be calculated, once the work to be done in each heater has been determined.

Either the Temperature-Entropy Chart or Mollier Diagram May Be Used

If the heat in B.t.u. required to raise the temperature of 1 lb. of water from the temperature at which it leaves the low-pressure heater, to that leaving the high-pressure heater is determined and the absolute temperature of the steam at the extraction point known, the entropy change can be calculated from Eq. 1 in Table I. Furthermore, the heat available in 1 lb. of bled steam under conditions at point P_1 can be calculated from Eq. 2. The entropy of steam in this particular case can be found either from the chart or from steam tables. As a rule, however, it is more convenient to take the entropy at this point from the chart, reading the proper value at the intersection of the turbine expansion line and the particular temperature or pressure line under consideration. Entropy of the water can be obtained from the steam tables. Only a fraction of the total heat available is required to raise the temperature of the feed water the desired amount and this proportion of the total steam can be calculated from Eq. 3.

Similarly, in the low-pressure heaters, the heat required to raise the temperature of the feed water the desired amount can be calculated from the temperature of the condensate entering and leaving the heater. In this heater, however, the condensed steam from the high-pressure heater goes down to the low-pressure heater and gives up a certain amount of heat as represented by Eq. 4. This reduces the amount of heat which it is necessary to extract from the turbine at the second bleed point.

In order to calculate the quantity of total steam bled through low-pressure heater, the entropy of the steam and the entropy of the water must be found as explained above for the new condition at T_2 or, if the Mollier diagram is being used, for P_2 instead of for T_2 as pressures are plotted on this diagram. Having determined these quantities the amount of steam can be calculated from Eq. 6 and the total amount of steam bled from both heaters is the sum of Eq. 3 and 6.

Thermal Efficiency Calculations Are Simple

In any system the thermal efficiency of the cycle is equal to one minus the quotient of the heat rejected divided by the heat supplied from the source. The heat supplied from the source is, of course, the total initial heat of the steam less the heat in the feed water to the boiler, as represented in Eq. 7. For a non-extraction turbine the heat rejected can be calculated from Eq. 8 and is made up of two parts, the first part representing the heat content of the exhaust steam as given by the product of the exhaust temperature and the entropy under the expansion line. The second item represents undercooling in the condenser, an item of almost negligible importance, with the present modern reheat hotwell where the temperature of the condensate is brought practically up to the temperature of the exhaust.

In an extraction turbine the heat rejected is given by Eq. 9 and is somewhat more involved as the first item representing the heat under the expansion line must be modified to allow for the steam extracted earlier in the cycle. This is shown by the heavily shaded area at the left side in Fig. 1 and is smaller than the corresponding area for a non-extraction turbine by the small lightly shaded portion on the right side of Fig. 1. The second item in Eq. 9 represents the heat taken to the condenser by the drain from the low pressure heater, while the third item corresponds to the second item in Eq. 8 and represents the loss due to undercooling in the condenser.

Application of the above equations and method of calculation is illustrated on Table II by means of an

example. A multi-stage turbine operating between the limit of 550 lb. per sq. in. absolute and 222.8 deg. F. superheat at the throttle and an exhaust pressure of 2 in. abs. of mercury is taken and it is assumed that the condensate leaves the condenser at 90 deg. F. and that the mean stage efficiency of the turbine is 75 per cent. The problem is to estimate the proportion of heating steam to the total steam flow and to find the thermal efficiency if the feed water is heated in two stages to the temperature corresponding to P_1 in Fig. 1.

Turbine Expansion Line Must Be Plotted

By plotting the expansion line for a stage efficiency of 75 per cent on the Mollier diagram, it is found that the steam reaches the saturation line at 48 lb. per sq. in. absolute. The corresponding saturation temperature is 278.5 deg. F. The feed water therefore has to be heated from the temperature of the condenser, or 90 deg. F. up to 278.5 deg. in two stages. If this temperature difference of 188.5 deg. is divided equally in the two heaters, the intermediate temperature is 184 deg. F. and the pressure is 8.20 lb. per sq. in. abs. The heat to be added in the high-pressure heater is 278.5—184 or 94.5 B.t.u. From Eq. 1 the change in entropy for this operation is found to be 0.128 which substituted in Eq. 3 with values of entropy as indicated in Table II gives 0.102 as the fraction of the total steam bled to the high pressure heater.

TABLE I. EQUATIONS FOR CALCULATING THE PERFORMANCE ARE SIMPLE AND EASILY DERIVED

FOR THE H.P HEATER

$$e_1 = \frac{h_1}{T_1} \quad (1)$$

$$H_1 = T_1(E_{S1} - E_{W1}) \quad (2)$$

$$W_1 = \frac{h_1}{H_1} = \frac{e_1}{E_{S1} - E_{W1}} \quad (3)$$

FOR THE L.P. HEATER

$$N = W_1(T_1 - T_2) \quad (4)$$

$$h_2 = L_2 - N \quad (5)$$

THEN AS FOR THE H.P HEATER

$$W_2 = \frac{h_2}{H_2} = \frac{e_2}{T_2(E_{S2} - E_{W2})} \quad (6)$$

THE HEAT SUPPLIED FROM THE SOURCE IS

$$Q_S = Q - (T_F - 492) \quad (7)$$

HEAT REJECTED FROM A NON-EXTRACTION TURBINE IS

$$Q_N = (E_{S3} - E_{W3})T_3 + (T_3 - T_C) \text{ B.T.U/LB.} \quad (8)$$

HEAT REJECTED FROM A 2 STG. EXTRACTION TURBINE IS

$$Q_E = (E_{S3} - E_{W3})T_3\left[1 - (W_1 + W_2)\right] + (W_1 + W_2)(T_2 - T_3) + (T_3 - T_C) \quad (9)$$

THERMAL EFFICIENCY

$$E_{ff} = \left(1 - \frac{\text{HEAT REJECTED}}{\text{HEAT FROM SOURCE}}\right)100 \quad (10)$$

E_{ff} = THERMAL EFFICIENCY IN PERCENT
E_{S1} = ENTROPY OF STEAM AT T_1
E_{S2} = " " " " T_2
E_{S3} = " " " " T_3
E_{W1} = " " " WATER " T_1
E_{W2} = " " " " T_2
E_{W3} = " " " " T_3
e_1 = CHANGE IN ENTROPY AT T_1
e_2 = " " " " T_2
H_1 = HEAT AVAILABLE IN STEAM AT T_1 IN B.T.U PER LB.
H_2 = " " " " " T_2 " " " LB
h_1 = HEAT REQUIRED FROM EXTRACTED STEAM IN H.P HTR.-B.T.U./LB.
h_2 = " " " " " " " " L.P " " "
L = TOTAL HEAT REQUIRED BY L.P. HEATER - B.T.U. PER LB.
N = HEAT CARRIED BY W_1 FROM H.P TO L.P HEATER-B.T.U.
Q = TOTAL INITIAL HEAT OF STEAM TO TURBINE B.T.U/LB.
Q_E = HEAT REJECTED BY AN EXTRACTION TURBINE " "
Q_N = " " " " A NON-EXTRACTION " " "
Q_S = HEAT SUPPLIED IN BOILER - B.T.U./LB.
P_1 = INTERSECTION OF TURBINE EXPANSION LINE & T_1, 1ST BLEED POINT
P_2 = " " " " " " & T_2, SEC. " "
P_3 = " " " " " " & T_3, EXHAUST
T_C = TEMP OF CONDENSATE DEG. F. ABS. = DEG F +460
T_F = " " FEEDWATER " " "
T_1 = " AT P_1 DEG. F. ABS. (FIRST BLEED POINT)
T_2 = " " P_2 " " " (SEC " ")
T_3 = " " P_3 " " " (EXHAUST)
W_1 = FRACTION OF TOTAL STEAM FLOW BLED FOR H.P HEATER
W_2 = " " " " " " " " L.P "

Heat required by the low-pressure heater is 184—90 or 94 B.t.u. but from Eq. 4, 9.5 of this B.t.u. are supplied by the drains from the high-pressure heater, leaving a balance of 84.5 B.t.u. to be supplied by extracted steam. Substituting the proper values in Eq. 5 and 6 gives 0.093 as the fraction of the total steam bled for the second heater. Adding these two values together it is found that 0.195 or 19.5 per cent of the total steam has to be extracted in order to heat the feed water temperature from 90 to 278.5 deg.

TABLE II. A CONSIDERABLE INCREASE IN THERMAL EFFICIENCY IS SHOWN BY EXTRACTION FOR FEED HEATING

550 LB. PER SQ. IN. ABS. 222.8 DEG. F. SUPERHEAT AT THROTTLE
EXHAUST PRESS. 2 IN. HG. ABS. (T_2 = 101° F = 561 °F. ABS.)
CONDENSATE TEMP. T_C = 90 DEG. F = 550° F. ABS.
MEAN TURBINE STAGE EFFICIENCY 75 PERCENT
FIND: THE PERCENTAGE OF STEAM BLED FOR TWO STAGE HEATING, THE THERMAL EFFICIENCY AND THE INCREASE IN THERMAL EFFICIENCY OVER NON-EXTRACTION OPERATION

FOR THE H.P. HEATER.

P_1 = 48 LB. PER SQ. IN. ABS. (FROM CHART)
T_1 = 278.5 °F. = 738.5 °F. ABS. (FROM STEAM TABLES)

$$T_2 = \frac{T_1 - T_2}{2} + T_C = \frac{278.5 - 90}{2} + 90 = 184\,°F. = 644\,°F. \text{ ABS.}$$

P_2 = 8.20 LB. PER SQ. IN. ABS. (FROM CHART)
$h_1 = T_2 - T_1 = 738.5 - 644 = 94.5$ B.T.U./LB
E_{S1} = 1.6613 FROM CHART
E_{W1} = 0.4077 " TABLES

FROM EQUATION 1

$$e_1 = \frac{h_1}{T_1} = \frac{94.5}{738.5} = 0.128$$

FROM EQ. 3

$$W_1 = \frac{e_1}{E_{S1} - E_{W1}} = \frac{0.128}{1.6613 - 0.477} = 0.102$$

FOR THE L.P. HEATER

E_{S2} = 1.720 FROM CHART
E_{W2} = 0.269 " TABLES

FROM EQ. 4.

$N = W_1(T_1 - T_2) = 0.102(738.5 - 644) = 9.5$
$L_2 = T_C - T_2 = 644 - 550 = 94$

FROM EQ. 5 AND 6

$h_2 = L_2 - N = 94 - 9.5 = 84.5$ B.T.U./LB.

$$e_2 = \frac{h_2}{T_2} = \frac{84.5}{664} = 0.131$$

$$W_2 = \frac{e_2}{E_{S2} - E_{W2}} = \frac{0.131}{1.720 - 0.269} = 0.0931$$

$W_1 + W_2 = 0.102 + 0.0931 = .195$ OR 19.5 % OF TOTAL STEAM FLOW TO TURBINE BLED FOR HEATING

TO FIND THE THERMAL EFFICIENCY

E_{S3} = 1.772 FROM CHART
E_{W3} = 0.1319 " TABLES
Q = 1354 B.T.U./LB. FROM TABLES

FOR NON-EXTRACTION

$T_F = T_C = 90\,°F. = 550\,°F.$ ABS.

FROM EQ. 7

$Q_S = 1354 - (550 - 492) = 1296$ B.T.U/LB.

FROM EQ. 8

$$Q_N = (E_{S3} - E_{W3})T_3 + (T_3 - T_C)$$
$$= (1.772 - 0.1319)561 + (561 - 550) = 931 \text{ B.T.U./LB.}$$

FROM EQ. 10.

$$E_{ff} = \left(1 - \frac{Q_N}{Q_S}\right)100 = \left(1 - \frac{931}{1296}\right)100 = 28.1$$

FOR AN EXTRACTION TURBINE

$T_F = T_1 = 278.5\,°F.$

FROM EQ. 7

$Q_S = 1354 - (738.5 - 492) = 1107.5$

FROM EQ. 9.

$$Q_E = (E_{S3} - E_{W3})T_3\left[1 - (W_1 + W_2)\right] + (W_1 + W_2)(T_2 - T_3) + (T_3 - T_C)$$
$$= (1.772 - 0.1319)561\left[1 - (0.102 + 0.093)\right] + (0.102 + 0.093)(644 - 561) + (561 - 550)$$
$$= 767.2 \text{ B.T.U./LB.}$$

FROM EQ. 10

$$E_{ff} = \left(1 - \frac{767.2}{1107.5}\right)100 = 30.4$$

30.4 − 28.1 = 2.3 PERCENT THERMAL EFF. GAIN DUE TO FEED HEATING BY EXTRACTION

Calculations for the various thermal efficiencies are given in some detail in Table II by using Eq. 7, 8, 9 and 10. These calculations show a thermal efficiency of 28.1 for the non-extraction turbine and 30.4 per cent for the extraction turbine, a gain in thermal efficiency due to feed water heating by extraction of 2.3 per cent.

Selecting the Most Economical Condenser

INLET TEMPERATURE OF THE CIRCULATING WATER, VELOCITY OF WATER IN THE TUBES, TUBE ARRANGEMENT AND DESIGN OF CONDENSER DETAILS WHICH MUST BE CONSIDERED WHEN MAKING A STUDY OF THE BEST CONDENSER TO BE USED. BY J. A. POWELL* AND H. V. VETLESEN*

AS A MEASURE of the relative size of the condenser, the ratio of square feet of condensing surface to the kilowatt output of the turbine has been used. This ratio has been gradually reduced during the last few years and the value now recommended by the different manufacturers varies widely, according to the condenser design of the individual manufacturer. Discussions of condenser installations which have appeared in technical papers recently have been merely technical. For the power plant engineer, the problem of selecting the most economical condenser for a particular unit is not merely technical, but is essentially an economic problem and has to be studied accordingly.

As it is not the aim of this paper to discuss the advantages or disadvantages of different makes of condensers, the study is based upon an average heat transfer in condensers of different makes which have actually been obtained under normal operating conditions. As a basis for the study, a load of 26,000 kw. on a 30,000-kw. turbo-generator bled at two stages for preheating the feed water up to 212 deg. has been assumed. Variation in steam flow to the turbine at this load with changes in vacuum were found and plotted as a water rate curve in Fig. 1 both with and without extraction for feed water heating.

Calculation of the vacuum which can be obtained with a condenser is based on the heat transfer obtained with tubes under normal operating conditions and not from the heat transfer obtained with absolutely clean tubes. This heat transfer, expressed in B.t.u. per square foot per degree F. per hour, varies with the inlet temperatures of the circulating water, with the velocity of the water in the tubes and with the tube arrangement and design of the condenser. A series of actual performance data on heat transfer for different makes of condensers with the tubes in normal operating condition were gathered and the curves of average values found at different inlet water temperatures plotted in Fig. 2. In the following study the average water inlet temperature was assumed to be 50 deg. F. and the corresponding heat transfer at different water velocities in the tubes was found from Fig. 2. This heat transfer gives the basis for the calculation of the vacuum obtained with any condenser with tubes of a certain gage and length as plotted on Fig. 3.

*Engineering Dept., the W. S. Barstow Management Association, Inc. From paper presented before the A. S. M. E. at Philadelphia.

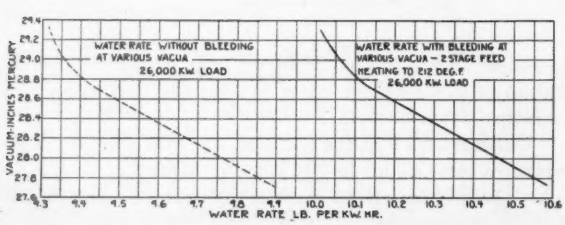

WATER RATE WITHOUT BLEEDING AT VARIOUS VACUA 26,000 KW LOAD
WATER RATE WITH BLEEDING AT VARIOUS VACUA – 2 STAGE FEED HEATING TO 212 DEG.F 26,000 KW LOAD
VACUUM-INCHES MERCURY
WATER RATE LB. PER KW HR.

FIG. 1. TURBINE CHARACTERISTICS DIFFER SOMEWHAT FROM STANDARD IF STEAM IS BLED FOR FEED WATER HEATING

Using the above data, curves showing the total yearly operating costs can be drawn for specific conditions as in Fig. 4. In this case only the friction head through the condenser was used, assuming that the siphon effect would be fully utilized. Steam conditions at the nozzle of the turbine were assumed to be 385 lb. gage, 700 deg. F. Coal was assumed to cost $4.50 per t. delivered, and the overall boiler efficiency was taken as 83.5 per cent. Condenser tubes were No. 17 B. W. G., 7/8 in. O. D. and 21 ft. long. Tube maintenance costs on condensers with more than 20,000 sq. ft. were figured at $0.07 per additional sq. ft. and a fixed charge made of 17 per cent on a capital investment of $3.00 per additional sq. ft. of surface. Auxiliary power was assumed to cost $40 per hp. year.

CURVES GIVE RELATIVE COSTS OF OPERATION

Total yearly operating costs thus shown do not represent absolute values, but are comparative figures, as only the difference in operating costs for tube maintenance, horsepower costs and fixed charges are tabulated. As comparative figures, the costs give, however, the information wanted regarding the most economical size and type of condenser to be installed.

As plotted, the curves show that the single-pass type of surface condenser, although requiring more circulating water is more economical than the two-pass type. If an ample supply of circulating water is available the single-pass condenser should be installed. The curves indicate that within the range of the condensers considered in this study, the condenser with the smaller surface is a more economical installation than the one with the larger surface. The economical advantage of installing a small condenser is more marked with a single-pass than with a two-pass condenser. The curves of the two-pass condensers show that with low water velocity the 25,000-sq. ft. condenser is just as economical as the 20,000-sq. ft. condenser. For the single-pass condenser, the 20,000-sq. ft. shows a marked economic advantage over the 25,000-sq. ft. condenser.

In order to determine whether a surface smaller than 20,000 sq. ft. would be advantageous, the yearly operat-

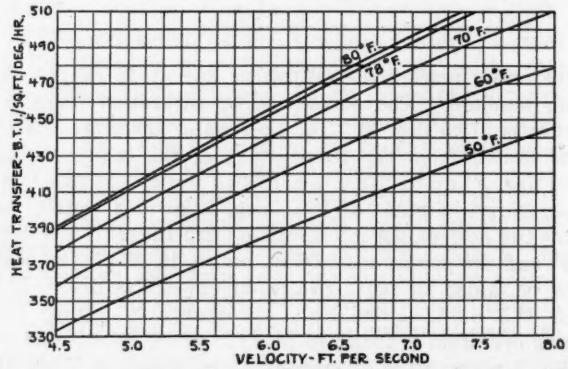


FIG. 2. TEMPERATURE OF THE INLET WATER HAS A CONSIDERABLE EFFECT ON THE HEAT TRANSFER

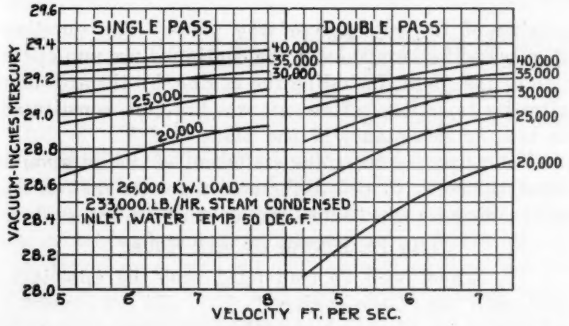


FIG. 3. UNDER SIMILAR CONDITIONS THE VACUUM OBTAINABLE VARIES WITH THE AREA OF THE CONDENSING SURFACE

ing cost for an 18,000-sq. ft. single-pass condenser was calculated and the corresponding curve added in Fig. 4. This curve indicated only a slight advantage over the 20,000-sq. ft. unit when the water velocity is over 2.65 ft. per sec., and a considerable loss at lower water velocity, showing that for the conditions considered it would not be advisable to install a single-pass condenser with less than 20,000-sq. ft. surface.

The ratio of condenser surface in square feet to normal turbine output in kilowatts is 20,000 to 26,000 or 0.77. This ratio for the most economical condenser installation is astonishingly low, especially when it is considered that the heat transfer assumed is an average value actually obtained and may be considered conservatively low compared with values guaranteed with modern condensers. An investigation regarding condenser installations in modern power plants shows that among forty, the most prominent power stations completed within the last two years, only two condenser installations have a ratio of condenser surface to kilowatt output under 1. This ratio for the different stations varies considerably, one being as high as 2.75, the average for all stations being 1.396. This study would indicate that the condensers generally installed have an excessive surface and that better economical results will be obtained when well-designed condensers with lower surfaces are installed.

High Water Velocities Lower Maintenance Charges

Water velocities in the tubes may have some influence on the cost for cleaning the tubes, as for high water velocities the scoring effect with the water in the tubes will increase and less frequent cleaning may be necessary. To express this effect as a saving in dollars and cents is difficult and no endeavor has been made to include this saving in the yearly operating cost. It is, however, advisable to have this in mind when the water velocity is determined.

As the mean inlet water temperature of the circulating water has considerable influence on the results, increasing mean inlet water temperatures will increase somewhat the amount of surface required for most economical condenser installation. The curves also show that with sufficient circulating water the most economical condenser installation unit is the single-pass condenser for which the ratio of surface to normal output of the turbine in kilowatts is not higher than 0.77. With higher water temperatures the installation of a smaller condenser is justified only at higher water velocities. At 60 deg. F. water temperature, the installation

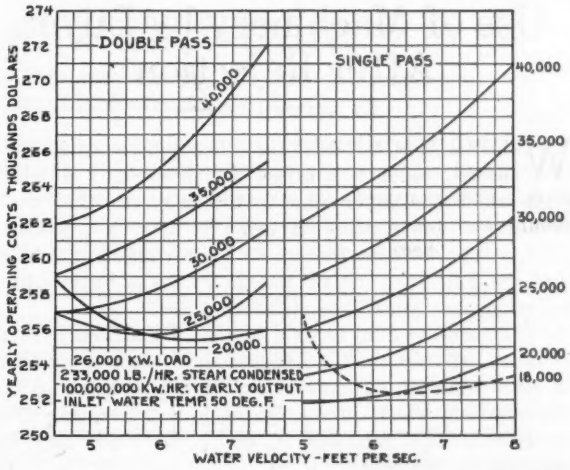


FIG. 4. THE MOST ECONOMICAL SURFACE TO USE UNDER DIFFERENT CONDITIONS CAN BE FOUND BY PLOTTING A SERIES OF CURVES SHOWING THE YEARLY OPERATING COSTS OF THE VARIOUS UNITS

of surface condenser with ratio of surface per kilowatt output of 0.77 is justified to water velocity through the tubes of 5.75 ft. per sec. and at 70 deg. F. water temperature for water velocities about 6.25 ft. per sec.

As the study made referred to special conditions, which, however, may be regarded as fairly normal, it may be questioned if the results obtained apply to con-

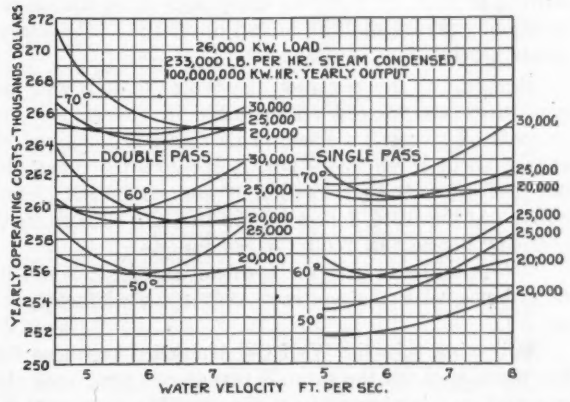


FIG. 5. SMALLER UNITS HAVE A MORE DECIDED ADVANTAGE AT LOW TEMPERATURES AND HIGH VELOCITIES

denser installations in general. The temperature of the circulating water is one of the main factors to be considered and further study shows that with water of 50 deg. F. a single-pass, 20,000-sq. ft. condenser is still the most economical for water velocities above 5.57 ft. per sec., and at 70 deg. water temperature the 20,000-sq. ft. condenser remains more economical than the 25,000-sq. ft. condenser for water velocities above about 6.25 ft. per sec.

Load factor may have influence on the result, but the single-pass, 20,000-sq. ft. condenser will show an advantage over the next larger condenser at all load factors considered. The advantage increases with lower load factors. For a two-pass type, a 25,000-sq. ft. condenser will be more economical to install than a 20,000-sq. ft. condenser at the highest load factor considered.

Use of Machinery by Buyer After Rejection

By Leslie Childs

WHERE MACHINERY or other equipment is purchased under a contract which permits a trial, after which the buyer may accept or reject, the latter should use due caution in using it after a rejection. This is true because the courts have consistently held that the continued use of machinery, by a buyer after rejection, may constitute an acceptance.

The possible danger to a buyer of machinery in a situation of this kind is illustrated in a great number of cases and, as an example of judicial reasoning on the question, Wolf Co. vs. Monarch Refrigerating Co., an Illinois case reported in 96 N. E. 1063, may be reviewed with profit.

Machinery Purchased with Right of Trial

In this case the refrigerating company entered into a contract with the other whereby it purchased certain machinery and equipment. The contract was in writing and, among other things, contained the following stipulation:

"After the plant is started, we [Wolf Co.] will furnish an engineer to have charge of the operation of the machine for ten days, * * *. At the end of the above-mentioned 10 days, you shall accept or reject the plant, * * *. If you reject, you shall notify us in writing thereof. * * * An acceptance after the above-mentioned period shall be in full discharge of the agreements hereinbefore contained."

Pursuant to this contract, the Wolf Co. delivered the machinery and placed an engineer in charge for the purpose of giving it a trial. This engineer remained in charge about three weeks but, it appears, the plant did not perform to the satisfaction of the refrigerating company. At any rate, following the test, the refrigerating company wrote the Wolf Co., as follows:

"We decline to accept the steam engine; it is not in accordance with the contract and is unsatisfactory to us."

Following this, the Wolf Co. demanded payment for the machinery, on the ground that it complied with the contract, and withdrew its engineer. The refrigerating company thereupon placed its own engineer in charge and continued to use the machinery in its business, though it apparently stood on its letter of rejection quoted above.

After the refrigerating company had used the plant about two months, the Wolf Co. brought the instant action to recover the balance alleged to be due. The refrigerating company denied liability and set up the fact that it had complied with the terms of the contract in its rejection of the machinery.

This, then, squarely raised the question of whether or not the use of the machinery by the refrigerating company, after its rejection, constituted an acceptance. The case reached the higher court on appeal and here in stating the point before it, the court said:

"It will be assumed for the purposes of this case, though we do not express any judgment about it, that the letters of the appellant [refrigerating company] declining to accept the engine constituted a notice in writing of the rejection of the plant. The questions then presented are whether the continued use and operation of the plant, including the engine, by the appellant after its rejection, before suit was brought, constituted, in law, an acceptance of the plant. * * *"

Following the foregoing statement of the question in hand, the court turned to the record for its answer, and in reaching its conclusion, among other things, said:

The Reasoning of the Court

"It cannot well be contended that the appellant's continued use of the engine * * * did not constitute an acceptance of the plant, unless the circumstances attending such use so qualified the act as to prevent its having the ordinary effect. The test was completed, the appellee had withdrawn its engineer, claimed to have performed its contract, and was demanding payment. The plant was then tendered in satisfaction of the contract.

"If it did not substantially conform to the contract, the appellant had the right to accept or reject it, at its option. If it chose to retain and use the engine, it thereby accepted the ownership of it. An act done by the buyer of the goods tendered in fulfillment of a contract of sale, which he would have no right to do if he were not the owner, constitutes, of itself, an acceptance of the goods. * * *

"Even though the appellant had determined to reject the plant, and though its letters * * * be regarded as sufficient notice in writing of such rejection, it could not retain the possession of the property and use it for its own profit in its business, and at the same time insist upon the rejection. The two things are utterly inconsistent. While the appellant is actually accepting and using the plant, its words of rejection are unavailing.

"Where machinery has been bought on approval, tried, found defective and unsatisfactory, and notice of rejection has been given, and where, nevertheless, the vendee has continued to use the machinery, such use amounts to a waiver of the right to return the machinery and an election to accept it. * * *"

In conclusion the court affirmed a judgment that had been rendered by the trial court in favor of Wolf Co. This for the reasons stated, i. e., the continued use of the machinery by the refrigerating company after rejection. In other words, such continued use constituted a waiver of the right to reject and rendered the refrigerating company liable for the amount due on the machinery.

Conclusion

In the light of the facts and holding of the foregoing decision, it is obvious that where machinery is purchased, with the right to reject after a trial, the buyer should be cautious in his use of such machinery after rejection. For, as illustrated in this Illinois case, such use may render void the rejection, and result in the buyer being held liable for the purchase price.

If, in such a situation, the buyer should desire for any reason to use the machinery after rejection, he should obtain permission so to do from the seller under another contract. In this manner his right to reject under the contract of purchase may be preserved. Otherwise, as we have seen, if following his rejection the machinery is used, such act may amount to an acceptance in a legal sense and render his rejection a nullity.

Oil Engine Cost and Test Data

Installation Costs and Operating Data of Diesel and Semi-Diesel Oil Engines

COMPARATIVE COSTS and other operating data obtained directly from the books of operating companies by unbiased investigators are rare indeed. The data submitted herewith, which was abstracted from the serial report on oil and gas engines by the Prime Movers Committee of the N. E. L. A., which has recently been issued, was obtained in this direct manner by a member of the committee who visited a number of stations. The lack of vague assumptions and of bias of any kind therefore adds much to the value of the data submitted.

Cost of Diesel Installation

In Table I these data are tabulated in terms of dollars, per kilowatt of rated capacity, for each comparison. The total overhead costs as reported are 7 per cent to 21 per cent of the specific construction costs, which are lower than overhead costs ordinarily chargeable to construction work of this kind. This difference is probably due to the fact that these engines were installed by operating organizations who charged to operation some costs properly chargeable to construction. Overhead costs for construction work of this character will in general be made up of items such as the following, at rates of the magnitude indicated below:

	Per Cent
Engineering and superintendence	5
Organization	2
Accounting and management	5
Legal	1
Taxes	1
Interest	4
Handling material (on material)	7
Liability and compensation (on labor)	6
Job overhead (on labor)	7

These items cannot be added (or used cumulatively) as they stand; for instance, the last three apply to a part of the specific costs only. Overhead costs will, however, frequently amount to 25 or 30 per cent of the specific cost. To Table I a line has been added showing total costs made up of specific costs plus overhead, which have been taken at 25 per cent.

Companies reporting costs for stations 1 and 2 advise that these include all costs of the complete Diesel electric generating stations. Station 6 was designed for two 200-kw. engines, of which only one was installed, and it is stated that costs include some auxiliary equipment of capacity suitable for two engines. The cost for this station, including 25 per cent overhead and after eliminating extra building, auxiliary equipment, etc., for the second engine, would have been around $260 per kw. Value of land is included in the costs for station 7 only. The engine in station 8 was installed in an existing building, the only building expense being for the engine foundation. As this was built as a standby station, no cooling tower or water treating equipment was installed. A comparison of detailed costs for this station with those for stations 6 and 7 will indicate that the cost complete including building, water cooling system, etc., would have been at least $230 per kw.

It may therefore be seen that the cost of complete stations of from 200 to 400 kw. capacity may be expected to be from $250 to $300 per kw. rating, which cost is reduced with increase in station capacity to approximately $200 per kw. for a 3500-kw. station.

Cost of Diesel Operation

Production cost statements have been obtained from several stations of various ages and capacities. A summary of these production costs for seven stations is given in Table II; the costs are for a twelve-month period, with the exception of stations 6 and 7 which are for a five-month period. In this table the same numbers are used to identify the stations as in Table I.

TABLE I. DIESEL ENGINE PLANT INSTALLATION COST IN DOLLARS PER KW. CAPACITY INSTALLED

No.	Item	*Plant Numbers 1	2	6	7	8
1.	Total plant capacity, kw.	3,500	1,000	200	400	240
2.	Date of installation, (approximate)	1916 1921	1923	1925	1925	1925
3.	Engines complete	88.60	97.50	98.20	92.30	89.60
4.	Generators & Exciters complete	20.00	11.00	Incl.in Item 3	Incl.in Item 3	Incl.in Item 3
5.	Cranes	0.70	2.20	.....	.....	.....
6.	Clutches, reduction gears, special drives, etc.	None	None	.....	.....	.....
7.	Switchboard & Wiring	2.20	5.00	31.10	15.52	5.40
8.	Auxiliary power units, air compressors, etc.	None	None	17.60	7.33	5.90
9.	Water pumps; water cooling and softening equipment	0.60	0.70	Incl.in Item 16	Incl.in Item 16	.....
10.	Lubricating oil, separators, purifiers, filters	0.60	0.50	.....	.....	.....
11.	Fuel oil pumping and clarifying equipment	0.20	0.20	.....	.....	.....
12.	Piping complete	4.30	6.00	22.15	14.40	4.23
13.	Shop equipment and tools	Use genl. shops	0.20	.....	.....	.....
14.	Freight and handling, all materials	9.70	15.60	3.86	1.60	2.87
15.	Miscellaneous materials	.....	.....	1.41	0.74	0.93
16.	Total machy. and equipment costs	126.90	138.90	174.32	132.99	108.83
17.	Land and Titles	no data	no data	not incl.	Incl.in Item 16	not incl.
18.	Bldgs.R.R.sidings, etc.	11.60	30.00	56.60	45.20	.....
19.	Foundations, including muffler pits, pipe trenches, etc.	8.60	10.00	Incl.in Item 16	Incl.in Item 16	4.17
20.	Lubricating oil storage	None	None	.....	.....	.....
21.	Fuel oil storage	0.90	1.20	.....	.....	.....
22.	Superintendence	1.40	2.00	.....	.....	.....
23.	Installation labor (not included above)	7.10	5.00	19.10	13.82	10.20
24.	Interest during construction	7.80	9.40	7.33	3.07	2.87
25.	Insurance (compensation)	Incl.in Item 24	Incl.in Item 24	0.94	0.94	0.25
26.	Acctg. stores, overhead	Incl.in Item 25	Incl.in Item 25	Incl.in Item 25	Incl.in Item 25	1.20
27.	Engrg. overhead	3.10	3.70	19.10	9.08	6.52
28.	Other overhead	.....	.....	26.10	19.55	10.70
29.	Total installation cost as reported	167.40	200.20	303.49	224.65	144.74
30.	Total installation cost allowing 25 per cent overhead on specific charges	196	234	313	240	156

* No data secured for plants 3, 4 and 5, for which data are given in Table II

In Table II but few items call for comment. The fuel oil cost per barrel varied from $1.36 to $2.69, presumably due to grade of oil used and location of plants with relation to fuel sources. This illustrates the importance of considering probable source and cost of fuel, in analyzing fuel costs to be expected in a Diesel station. The figures for maintenance cost vary from about 0.5 mill to 10.5 mills per kw-hr., this wide variation again illustrating the difficulty of arriving at any average maintenance cost for a Diesel engine to be assumed for any specific installation. Maintenance costs may be expected to be low the first three or four years of operation, and after that, will vary widely from year to year, depending on necessity for replacement of bearings, cylinder liners, pistons, etc. There will also be a wide variation between stations, depend-

TABLE II. DIESEL PLANT OPERATING DATA AND COSTS

No.	Item	Plant Numbers 1	2	3	4	5	6	7
1.	Total plant capacity, Hp.	5000	1500	.....	1925	500	300	600
2.	Total plant capacity, Kw.	3500	1000	.....	1355	421	200	400
3.	No. units, 2-stroke cycle	0	0	.....	0	0	1	2
4.	No. units, 4-stroke cycle	5	2	.....	5	3	0	0
5.	Size of units, Hp.	5-1000	2-750	.....	3-225 1-500 1-750	2-150 1-200	1-300	1-240 1-360
6.	Age of engines	3-10 yr. 2- 5 yr.	3 yr.	.....	.....	.....	1 yr.	1 yr
7.	Annual net station output, kw.hr.	12454200	4354295	3468197	2383644	252780**	271559**	293109
8.	Station capacity factor* per cent	41.0	50.5	.....	23.4	8.0	40.0	22.0
9.	Peak load - Kw.	2850	1100	.....	800	118	.....	.....
10.	Station load factor* - per cent	50.3	45.9	.....	39.7	28.5	.....	.....
11.	Station output factor* - per cent	67.5	61.9	.....	50.0	.....	.....	.....
12.	Fuel oil used, bbl.	27120	9595	6168	6161	1094	.....	.....
13.	Specific gravity of oil used, Deg. Be.	20-22	24-30	.....	.....	24-26	.....	.....
14.	Fuel oil B.t.u. per lb., B.t.u.	18940	19300	19000	18000	19220	.....	.....
15.	Average fuel used per kw.hr. output, lb.	0.76	0.69	0.74	0.81	1.38	.....	.....
16.	Average B.t.u. per kw. hr. output, B.t.u.	14400	13300	14050	14580	26500	.....	.....
17.	Cost of fuel oil per bbl., dollars	1.36	1.375	1.98	2.30	2.69	.....	.....
18.	Labor cost total (not including maintenance) - dollars	22464	8660	8344	8176	4957	1864	1549
19.	Labor cost, average per man day (not including maintenance labor) - dollars	4.40	5.25	.....	.....	.....	.....	.....
20.	Lubricants used, gal.	7350	2664	.....	1800	1226	.....	.....
21.	Engine hrs. per gal. of lubricant	3.62	5.37	.....	7.30	6.03	.....	.....
22.	Maintenance cost - total, including labor - dollars	29838	3000	11121	1201	2667	340	588
23.	Miscellaneous cost total - dollars	Incl. under Maintenance	1000	294	.....	263	205	1188
24.	Production cost total - dollars	93902	27719	39245	24623	11580	5185	6183
25.	Fuel cost per kw.hr. output - mills	2.96	3.01	4.66	5.94	11.67	9.26	8.42
26.	Labor cost per kw.hr. output - mills	1.81	1.97	2.40	3.43	19.56	6.86	5.29
27.	Cost of lubricants per kw.hr. output - mills	0.38	0.43	0.96	0.45	2.95	0.97	1.33
28.	Maintenance cost per kw. hr. output - mills	2.39	0.69	3.21	0.50	10.54	1.25	2.01
29.	Miscellaneous cost per kw. hr. output - mills	Incl. under Maintenance	0.23	0.08	.....	1.04	0.76	4.05
30.	Production cost per kw. hr. output - mills	7.54	6.33	11.31	10.32	45.76	19.10	21.10

*For definition of factors see N.E.L.A. Bulletin T3-22 "Report of Prime Movers Committee" page 339. This also appears in the N.E.L.A. Proceedings, 1922, Vol. 2, pages 911 and 912.
**Five months' operation.

ing on load factor, and quality of operation, inspection and maintenance. Again, poor water conditions will result in cylinder head and piston failures which make for high maintenance.

In the 1924-25 report, Table III showed operating costs for five stations averaged for four years. In Table III of this report similar tabulation is made for the same plants over a six-year period. There has been an increase in station capacity factor and a decrease in nearly all unit costs as compered with the report for the four-year period. In an effort to decrease maintenance costs the operators of these stations have reduced the peak load on generators during the past 2 yr., with the result that even with a lower average hourly load (when in service), the annual output has increased because the engines were not out of service for

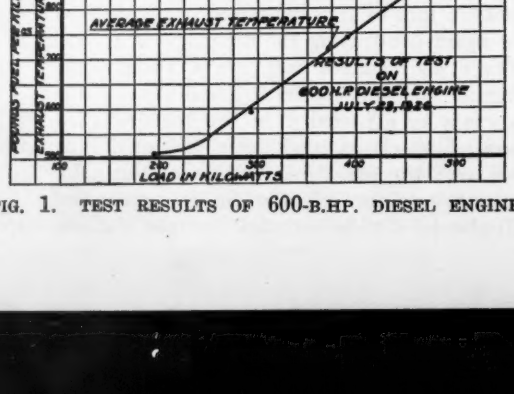

POUNDS OF FUEL PER KW-HR.
AVERAGE EXHAUST TEMPERATURE
RESULTS OF TEST ON 600 H.P. DIESEL ENGINE JULY 23, 1926.
POUNDS FUEL PER KILOWATT HOUR
EXHAUST TEMPERATURE
LOAD IN KILOWATTS

FIG. 1. TEST RESULTS OF 600-B.HP. DIESEL ENGINE

maintenance work as many hours in the year. The company operating these five stations and six other oil engine stations now limits the maximum load regularly carried on oil engines to 80 per cent of the brake horsepower rating of their engines; as indicated in Table III, it has been found that this improves reliability and reduces maintenance expense.

Station A has been connected to the transmission system by one line during the six-year period covered by this report, but 2 yr. ago another line giving a two-way feed was completed. The other four stations have been connected to the transmission system within the last 2 yr. During 1926, as a result of the improvements in the transmission system and the construction of a modern steam station, two of these stations have been placed on a standby basis and the other three are operating only as needed for voltage regulation or to insure service in case of transmission line failure.

TABLE III. RESULTS OF OPERATION OF DIESEL ENGINES. DATA FOR 6-YR. PERIOD ENDING DECEMBER 31, 1925

	Station A	Station B	Station C	Station D	Station E
1. Number, size and kind of Diesel units	3-500 h.p. M&S Diesel gen. 3-310 Kw. rating G. E.	4-225 h.p. M-S Diesel gen. 1-300 Kw. rating G. E. 2-500 h.p. M-S Diesel gen. 1-310 Kw. rating G. E.	3-225 h.p. M-S Diesel gen. 1-150 Kw. rating G. E. 2-300 h.p. M-S Diesel gen. 1-200 Kw. rating G. E.	1-600 h.p. M&S Diesel gen. 1-450 Kw. rating G. E. 1-170 h.p. M-S Diesel gen. 1-150 Kw. rating G. E. 1-125 h.p. M-S Diesel gen. 1-100 Kw. rating G. E.	1-600 h.p. M&S Diesel gen. 1-310 Kw. rating G. E.
2. Total Diesel plant capacity, kw.	930	600-910	450	735	310
3. Gravity of fuel oil (average) (22-26°Be)	0.9-0.92	0.9-0.92	0.9-0.92	0.9-0.92	0.9-0.92
4. B.t.u. per lb. of fuel (average)	19,000	19,000	19,000	19,000	19,000
5. Net station output, kw. hr.	37,421,000	14,361,496	6,634,025***	14,342,865	11,942,776
6. Maximum hr. generation, kw.hr.	1,140	790	540	730	350
7. Six years' maximum peak, kw.	1,160	840	568	740	350
8. Station capacity factor, per cent****	76.7	35.0	28.0	37.2	73.5
9. Fuel used, total bbl.	83,447	36,705	19,489	37,594	27,788
10. Lb. fuel per kw. hr. output	0.70	0.85	0.92	0.82	0.73
11. B.t.u. per kw.hr. output	13,300	16,080	17,537	15,637	13,870
12. Lubricants in gal. per M kw.hr. output	0.84	1.67	1.96	1.85	0.79
13. Engine maintenance cost per kw.hr. output - mills	2.80	4.55	6.91	6.26	2.80
14. Fuel cost per kw.hr. output-mills	3.73	4.78	4.84	4.94	4.09
15. Lubricant cost per kw. hr. output-mills	0.42	1.19	1.08	1.04	0.53
16. Total maintenance cost per kw.hr. output - mills	2.96	4.88	7.57	6.95	3.14
17. Miscellaneous supplies per kw.hr. output - mills	0.36	0.75	0.87	0.63	0.56
18. Labor cost per kw.hr. output-mills	1.89	3.74	5.60	3.32	2.79
19. Water cost per kw.hr. output-mills	0.07	0.07	0.10	0.15	0.21
20. Production cost per kw.hr.output-mills	9.43	15.41	20.06	17.03	11.32

*Installed June 1, 1922.
**Increase due to new unit; 750 shown in last report included 150-kw. unit which was omitted from this report as it was operated for less than one month and has not been listed under Item No. 1.
***Includes 131,290 kw-hr. generated by gas engine from 1922 to 1925, inclusive, performance data of which could not be segregated from Diesel figures.
****Station capacity factor is same factor as station load factor shown in Table III in previous reports. For definitions see N. E. L. A. Bulletin T3-22, "Report of Prime Movers Committee," p. 339. (This also appears in the N. E. L. A. Proceedings, 1922, Vol. 2, pages 911 and 912.) The figures given are based on net station output, according to practice established in previous reports, instead of gross output specified by definition.

Note: The Diesel engines at the stations represented in the above tabulation vary in age from 4 to 20 yr. All engines in Station A, D and E have been giving continual service, with the exception of time lost for regular maintenance and repair periods. The four 225-hp. engines in Station B have been operated only for standby service since June 1, 1924. Station C has been operated only for standby service since June 1, 1925.

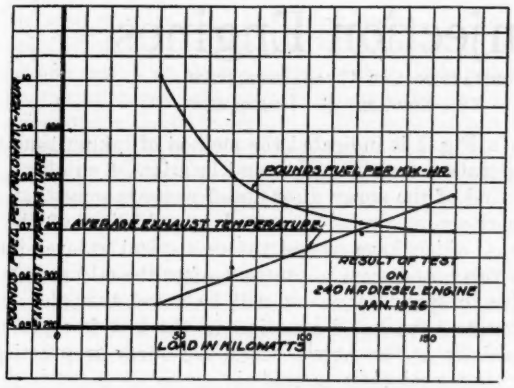


FIG. 2. TEST RESULTS OF 240-B.HP. DIESEL ENGINE

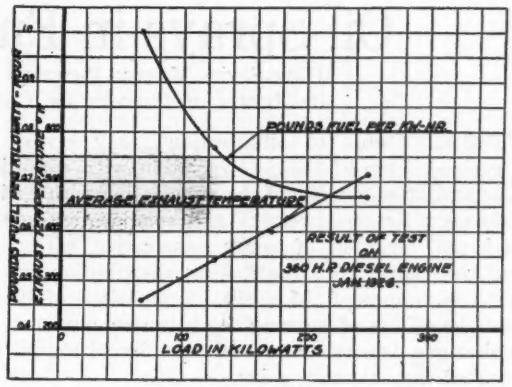


FIG. 3. TEST RESULTS OF 360-B.HP. DIESEL ENGINE

Diesel Test Results

Figures 1, 2 and 3 show the results of tests on three oil engines recently installed. Figure 1 is for a six-cylinder, 600-br.hp. Diesel engine; Fig. 2 is for a four-cylinder, 240-br.hp. Diesel engine and Fig. 3 is for a six-cylinder, 360-br.hp. Diesel engine. Assuming oil having a heat value of 19,000 B.t.u. per lb., these curves show a heat consumption at best point of 11,000, 13,300, and 12,800 B.t.u. per kw-hr., respectively. It is stated that these curves represent net generator output after deduction of energy for excitation. Energy for station light and power, amounting to two or three per cent of energy generated, should also be deducted to get net station output.

Semi-Diesel Field

There has been little new development in the field of the semi-Diesel and hot bulb engines, although there have been some improvements and refinements in design. There seems to be a trend toward the use of full type Diesel engines in the smaller sizes in the field for which the semi-Diesel units have heretofore been considered to be peculiarly fitted.

TABLE IV. SEMI-DIESEL PLANT OPERATING DATA AND COSTS

No.	Item	Plant Numbers 13**	14***
1.	Total plant capacity - h.p.	500	650
2.	Total plant capacity - kw.	336	420
3.	No. units, 2-stroke cycle	2	3
4.	No. units, 4-stroke cycle	0	0
5.	Size of units - h.p.	1-200 1-300	3-150 2-100
6.	Age of engines - yr.	1 to 3	3 to 7
7.	Total gross station output-kw-hr.	1,033,270	1,773,727
8.	Station capacity factor* - per cent	35.1	32.1
9.	Peak load - kw.	330	320
10.	Station load factor* - per cent	35.7	42.2
11.	Station output factor* - per cent	62.5	57.4
12.	Fuel oil used - bbl.	2,609	6,165
13.	Specific gravity of oil used-deg.Be.	26	28-30
14.	Fuel oil B.t.u. per lb. - B.t.u.	19,000	19,000
15.	Average fuel used per kw-hr.gross output - lb.	0.789	1.074
16.	Average B.t.u. per kw-hr.gross output - B.t.u.	14,970	20,400
17.	Cost of fuel oil per bbl. - dollars	1.96	2.19
18.	Labor cost total (not incl. maintenance) - dollars	4,207	6,429
19.	Labor cost, average per man-day (not incl. maintenance labor)-dollars	3.85	3.91
20.	Lubricants used - gal.	2,250	7,291
21.	Engine hrs. per gal. of lubricant	4.05	4.94
22.	Maintenance cost total, incl. labor-dollars	1,510	7,587
23.	Miscellaneous cost total - dollars	972	995
24.	Production cost total - dollars	12,853	31,933
25.	Fuel cost per kw-hr. output-mills	4.94	7.62
26.	Labor cost per kw-hr. output-mills	4.07	3.63
27.	Cost lubricant per kw-hr.output-mills	1.01	1.92
28.	Maintenance cost per kw-hr.output-mills	1.46	4.27
29.	Miscellaneous cost per kw.-hr.output-mills	0.94	0.56
30.	Production cost per kw-hr.output****-mills	12.42	18.00

*For definition of factors, see N. E. L. A. Bulletin T3-22, "Report of Prime Movers Committee," page 339. This also appears in the N. E. L. A. Proceedings, 1922, Vol. 2, pages 911 and 912.

**Includes three months' operation of 400-hp. Diesel engine. Figures based upon a period of 12 mo.

***Figures based upon a period of 18 mo.

****Production cost, including all factors making up these figures, are based on gross instead of net station outputs, because plants were not equipped with station service meters.

Cost of Semi-Diesel Operation

For several years past the committee has endeavored to get operating costs for the smaller semi-Diesel stations, but has not been able to do so, as few are operated by member companies. This year the committee has been fortunate enough to obtain average production costs for a period of 11½ mo. for one station and 18 mo. for another. These data are shown in Table IV.

Gas Engine Pistons Renewed

WHEREVER gas engines are used, there is accompanying wear on pistons and cylinders which, in time, will result in slapping and loss of compression. To replace pistons is expensive and, frequently, worn pistons can be reclaimed by welding bronze bands to the piston by means of the oxyacetylene torch.

First remove all grease and dirt by washing thoroughly in gasoline, allowing the piston to dry by gas evaporation. Then, on a welding table, and with a hot acetylene flame the tip of which should be governed by the thickness of the metal and the experience of the operator, the top side of the piston is brought to a dull red heat. From a bronze rod that has been warmed, dipped in flux and placed under the flame, a thin layer of bronze is flowed on. As the work progresses, the piston is rotated on its edge until the band of bronze is completed. A band welded after this fashion on each end of the piston will give good results. While they may be of any width, the wider the bands the better the bearing surface.

When cooled the pistons are machined to fit the cylinders, and new rings are provided. Bronze-banded pistons will serve as well as, if not better than, new ones. Only the best obtainable grade of bronze and flux should be used for this work.

LUBRICATING oil for an internal combustion engine can be considered as giving good results and lubricating effectively if, with its use, there is a minimum danger of lubrication failure and if its consumption is not excessive.

Oil Sprays in Fuel Injection Engines

High-Speed Motion Pictures Show Formation and Characteristics of Jets and Effects of Conditions.

By Edward S. Beardsley

VISUAL studies of oil-injection spray reveal the general form of the jet, variation with conditions before and after cutoff and the atomization with various jet forms. By measurement and computation can be found the variation of spray penetration with time, cutoff time, spray cone angle, spray distribution and the growth in volume of the spray. Comparison of studies shows the effects of varying the injection pressure, the chamber gas density, the specific gravity of the oil and design of the injection valve.

These results were presented before the spring meeting of the A. S. M. E. by Mr. Beardsley, who described the apparatus for taking these ultra high-speed motion pictures and indicated the wide range of investigation which this method opens up.

FIG. 1. MEDIUM CENTRIFUGAL SPRAY WITH DIESEL OIL, 0.85 SP. GR. AT 8000 LB. PER SQ. IN. INJECTION PRESSURE INTO COMPRESSED AIR CHAMBER AT 200 LB. PRESSURE

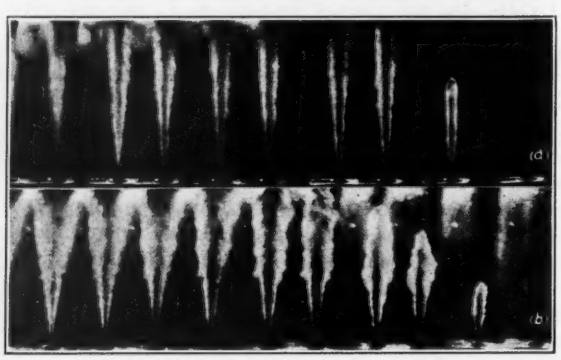


FIG. 2. NON-CENTRIFUGAL SPRAY AT 8000 LB. PRESSURE; (a) INTO ATMOSPHERIC PRESSURE; (b) INTO 200 LB. CHAMBER PRESSURE

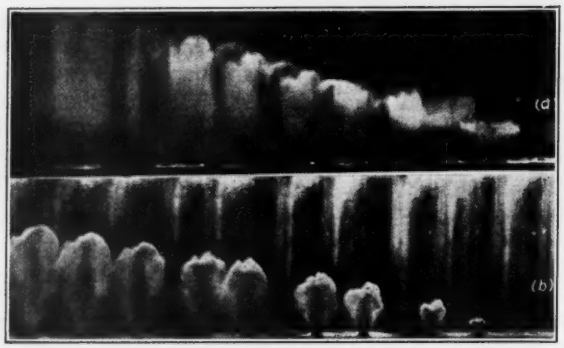


FIG. 3. HIGH CENTRIFUGAL SPRAY AT 8000 LB.; (a) INTO ATMOSPHERIC PRESSURE; (b) INTO 200 LB. PRESSURE

In Fig. 1 is indicated the method of taking time and penetration measurements and location of cutoff.

End of the spray after cutoff appears somewhat like a cork-screw, probably caused by whirling of the oil drops, which have passed through spiral grooves inside the valve, and seem to continue after the oil has left the valve in spray form. It will be noted that the spray seems to have lost its motion in the last few pictures, especially at the nozzle where the spray is practically hanging motionless in mid-air.

Penetration-time curves are plotted from data computed from measurements of the spray images on each film, taking into account the film speed and photographic reduction as shown. The spray volumes are computed by summation of the differential cylinders making up each spray.

Photographs Show Spray Characteristics

In Fig. 2, non-centrifugal sprays, the sprays appear somewhat like fir trees with drooping branches, because the velocity of the drops of oil is practically zero at the outside of the spray and increases toward the center. The oil seems to shoot out through the center and spill over on the sides, much like a fountain of water. On the sides of the sprays, clouds of oil particles appear as bumps, which do not change their position from one picture to another. They show that the oil particles outside of the spray are motionless. The included angle for these sprays was increased 50 per cent by injection into dense air. The atomization also appears to be increased, as shown by the pictures.

High-centrifugal sprays injected into the atmosphere and into 200 lb. per sq. in. air pressure are shown in Fig. 3. The reduction in the spray angle with the spray injected into dense air is about 40 per cent, which may explain the failure of some centrifugal valves to operate successfully in an engine when the spray appeared well suited for the engine combustion chamber from observations made in the atmosphere. This decrease of spray-cone angle is characteristic of all centrifugal sprays.

Figure 4, of two sprays, shows the effect of larger

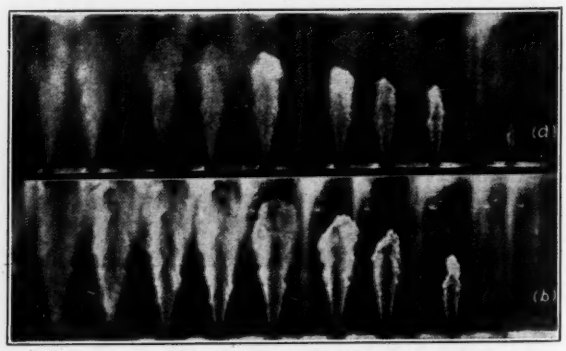


FIG. 4. CENTRIFUGAL SPRAY AT 8000 LB. INTO 200 LB. CHAMBER PRESSURE WITH RATIO ORIFICE AREA TO GROOVE AREA 0.19; ORIFICE AREA (a) 0.000113 SQ. IN.; (b) 0.00038 SQ. IN.

orifice and grooves for the second spray, where the quantity of oil injected was nearly three times as great.

In one test a small secondary spray discharge was shown taking place after cutoff, thought to be caused by a pressure wave in the oil line. It was eliminated by increasing the length of the injection-valve tube, thus damping out the pressure wave because of the increased friction and greater oil volume.

Effect of Injection Pressure

Figure 5 shows the effect of varying injection pressures. The curves are almost straight and parallel, which shows that the penetration increased nearly in proportion to the injection pressure, a characteristic result. There is, of course, a limit beyond which increase in the injection pressure would not increase the penetration and might even decrease it, when the drops are atomized so finely as to be too light to penetrate the dense air. The injection pressure affects the spray-cone angle as well as the penetration, increase in the injection pressure causing a narrower spray-cone angle with a non-centrifugal valve, and a wide spray-cone angle with a high-centrifugal valve.

Effect of Gas Density

Figure 6 shows the effect of chamber-gas pressure and density upon the spray penetration, the main curves being cross plotted from the curves shown in the insert, which are for nitrogen gas, and from similar curves obtained with helium and carbon dioxide gas in the chamber. Each point is labelled as to the gas which was used in obtaining it. The points obtained by injection into the various gases were all plotted on a basis of absolute gas density. As all of the points lie on the curves, showing that it is the absolute density of the gas which controls spray penetration, that the viscosity of the gases has no appreciable effect and that pressure affects the penetration only in so far as it controls the density. This indicates that it is the density of the gas in the engine which controls spray penetration in an engine cylinder and not the compression pressure.

Specific gravity of the fuel used was cross-plotted from the curves for heavy fuel oil shown in the insert,

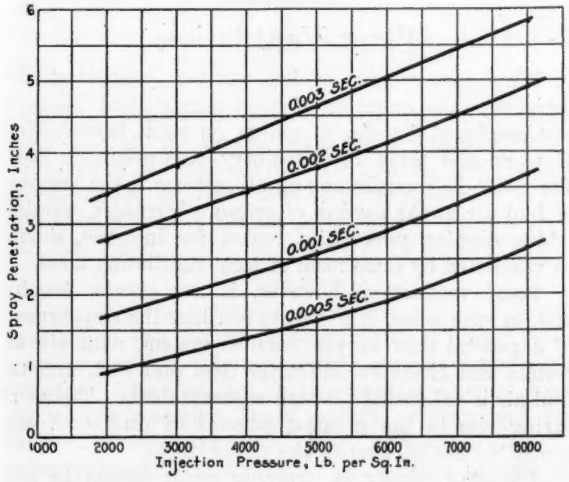


FIG. 5. PENETRATION INCREASES WITH INJECTION PRESSURE. CONDITIONS OF FIG. 1 WITH SPRAY PRESSURE VARIED; ORIFICE 0.0155 IN. DIAM. CHAMBER FILLED WITH NITROGEN

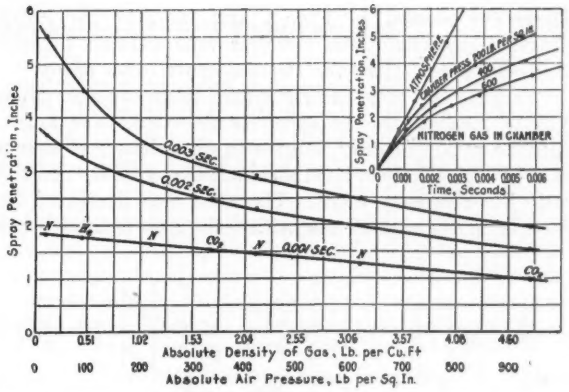


FIG. 6. PENETRATION VARIES WITH CHAMBER GAS DENSITY; 23-DEG. SPIRAL GROOVES; ORIFICE 0.022 IN. DIAM.

Fig. 7, and from similar curves for the other fuel oils. The penetration is seen to increase with the specific gravity and, from the upward trend of the curves, oils of greater specific gravity than those tested would have still greater effects. From the curves, a heavy oil of 0.90 sp. gr. would have 10 per cent greater penetration after 0.003 sec. than an ordinary Diesel oil of a sp. gr. of 0.85. The heavy oil is more viscous than the others, and is not as readily atomized, which makes the spray angle narrower and helps to produce greater penetration.

Effect of Valve Design

The effect of the groove-helix angle to the nozzle face on the penetration, cone angle, and ratio of spray volume to oil volume is shown in Fig. 8. The penetration increases considerably with increase in the angle of the spiral grooves, the 90 deg. or non-centrifugal spray having 60 per cent greater penetration after 0.003 sec. than does the 23-deg. high-centrifugal spray. The spray angle was decreased from 53 deg. to 23 deg. by this same increase in the groove-helix angle.

To find the relative distribution, and to obtain an indication of the atomization of the spray, the actual spray volumes were computed. The quantities of oil injected with each valve set-up were, however, different, so, in order to put them all on the same basis, the ratios of spray volume to oil volume were computed.

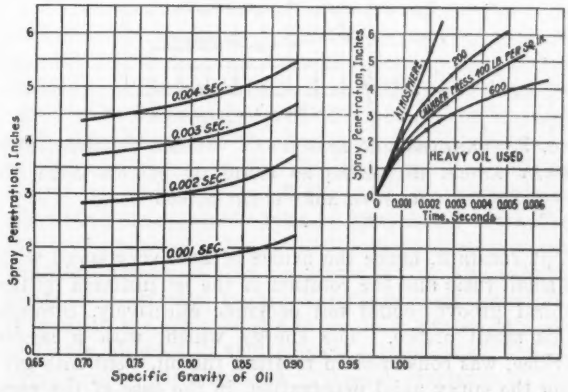


FIG. 7. PENETRATION INCREASES WITH SPECIFIC GRAVITY OF OIL; SAME CONDITIONS AS FIG. 6; CHAMBER GAS, AIR AT 200 LB. OILS OF SP. GR. OF 0.705, 0.799, 0.85 AND 0.90

These are plotted in Fig. 8 and indicate the spray distribution, which was 100 per cent greater for the high-centrifugal than for the non-centrifugal spray.

Varying the ratio of orifice area to groove area from 0.19 to 2.05 affects the spray penetration, cone angle, and the ratio of spray volume to oil volume, as shown in Fig. 9. The penetration increases rapidly as the ratio becomes very small. The ratio was decreased by decreasing the size of the orifice, the groove area being

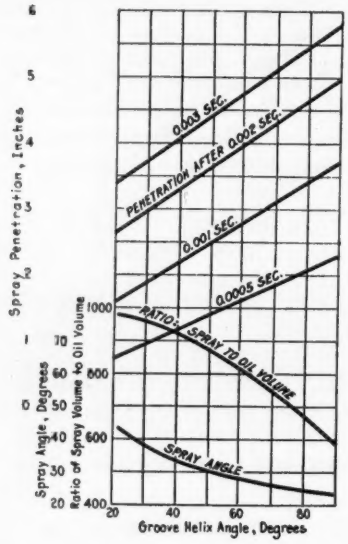


FIG. 8. PENETRATION INCREASES, SPRAY ANGLE AND SPRAY VOLUME DECREASE WITH INCREASE OF ANGLE OF GROOVE HELIX TO FACE OF NOZZLE

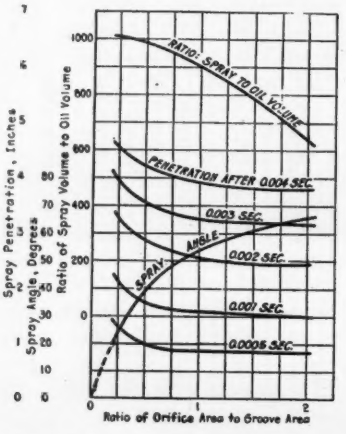


FIG. 9. PENETRATION AND SPRAY VOLUME DECREASE BUT SPRAY ANGLE INCREASES AS RATIO OF ORIFICE AREA TO GROOVE AREA IS INCREASED

kept constant, hence the orifice became very small with a small ratio and the rotation of the jet initiated by the spiral grooves could not continue effectively, through this small orifice. The energy which, with a larger orifice, was consumed in rotating the oil, went into giving the spray axial penetration, in the case of the very small orifice. The spray angle was therefore reduced, and this is shown by the spray-angle curve. The shape of this curve seems to indicate that the spray angle would not be greatly increased by increase in the ratio beyond 2.0.

The curve at the top of Fig. 9 would seem to indicate that the orifice size has considerable effect upon the spray distribution and possibly atomization.

Installing Cylinder Head Gaskets on Gasoline Engines

CYLINDER head gaskets in a heavy duty type of engine require more attention than is necessary in the case of the automobile engine. When installing a new gasket, according to instructions recently issued by The Climax Engineering Company, Clinton, Iowa, the operator should proceed as follows:

1. Clean all surfaces.
2. Place gasket on head with the dark side down and shift on studs until all water openings index properly.
3. Put on head and draw the stud nuts down beginning with the nuts in center portion of head until all are just bearing on head.
4. Tighten the nuts gradually, working back and forth across, not around, the head, always keeping more tension on the nuts in center portion of head. Continue until all nuts are drawn tight.
5. Run engine without load until thoroughly warmed up. Stop and go over all nuts again beginning with the nuts in center portion of head.
6. Tighten nuts frequently and persistently for three or four days until the gasket is finally compressed and nuts can be turned no further. Particularly should this be done in the case of a new engine going into service.

When heads are removed for grinding valves it is good to install new gaskets although frequently the old gaskets can be successfully used again if they are not damaged and have been carefully installed.

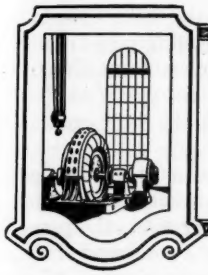
Operators who follow these simple rules will avoid engine trouble which might cause delay and a consequent loss in profits and production time to the engine power.

Plant Ventilation

WITH THE COMING of hot weather, ventilation deserves the close attention of every management. Methods best employed depend, of course, on plant layout, kind of work and types of machinery or equipment used. The point in common among all systems is the removal of foul air *at the sources of origin.* Furnaces, welding tables, dipping pots, paint rooms, for instance, should be ventilated by some form of local ventilating hood.

Local ventilation, however, is not always feasible and, in such cases, it is well to consider the employment of a general dust or gas removal system, with air arresters and filters to collect the dust and dirt, and the foul air is exhausted through separate ducts. The work giving rise to the greatest amount of dust or fumes should be placed nearest the outlet ducts.

Plentiful supply of drinking water should be provided at suitable fountains or outlets throughout the plant, and adequate washing facilities will prove a good investment.



ELECTRICAL MACHINERY FOR LIGHT AND POWER

Short Circuit Phenomena in the Power Plant

THE FIRST OF A SERIES OF THREE ARTICLES OUTLINING IN ELEMENTARY FASHION THE ENGINEERING PROBLEMS DUE TO SHORT CIRCUITS ON POWER SYSTEMS. BY W. F. SUTHERLAND

DESIGNING POWER plant equipment to withstand the enormous forces developed under short-circuit conditions is a problem having much in common with the old problem of the irresistible force and the immovable object. A contest between the rapidly increasing capacity of modern generating stations and the ingenuity of the designer has been going on for some time and like the more or less similar rivalry existing between the safe builder and the yegg, finality has hardly been reached.

In the design of station equipment, it becomes necessary to ascertain the probable upper limit of the currents likely to flow when trouble develops and to estimate, as accurately as the approximate nature of the data will allow, the effect of such currents on the equipment involved. The present series of articles outlines, in by no means an exhaustive fashion, some of the interesting features of the problem and introduces the reader into a fascinating branch of electrical engineering.

Three factors affect the flow of current under short circuit conditions: inductance, resistance and capacity. Resistance is a negligible factor and is usually not considered in any calculations being made; capacity occasionally is of importance where lead covered cables are installed but this too is neglected with a resulting simplification of the work involved. Inductance, on the other hand, is of much importance in the limiting of current flow and expressed as reactance it forms the basis for such calculations as are necessary.

The magnetic field and the flow of electricity are inevitably associated; wherever current is present a magnetic field is present; wherever a magnetic field is varied in its interlinkage with a conductor, electromotive forces are set up which tend to cause electricity to flow and this in such direction as to oppose the change in flux creating it.

TRANSFORMERS

An alternating current transformer is an excellent example of this inductive phenomenon. Under conditions of no-load, only an exciting current flows in the primary. The flux due to this exciting current gives rise to electromotive forces in both primary and secondary, which in the case of the primary oppose the primary e.m.f. and thus limit the current to that required for excitation. Under load, however, a readjustment of this equilibrium condition takes place; the secondary induced e.m.f. now causes current flow in the secondary windings and exterior circuit, the primary counter-e.m.f. being decreased to a value permitting the flow of the corresponding primary load current.

A perfect transformer would thus show a strict proportionality between primary current and secondary

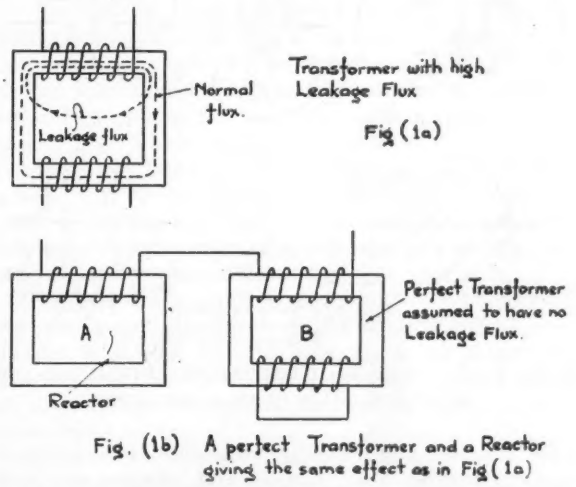

Normal flux.
Leakage flux
Transformer with high Leakage Flux
Fig (1a)
A
B
Reactor
Perfect Transformer assumed to have no Leakage Flux.
Fig. (1b) A perfect Transformer and a Reactor giving the same effect as in Fig (1a)

FIG. 1. TRANSFORMER DIAGRAMS ILLUSTRATING MAGNETIC LEAKAGE

impedance, as the latter decreased so would the former increase and a short-circuited secondary would be equivalent to a short-circuited primary.

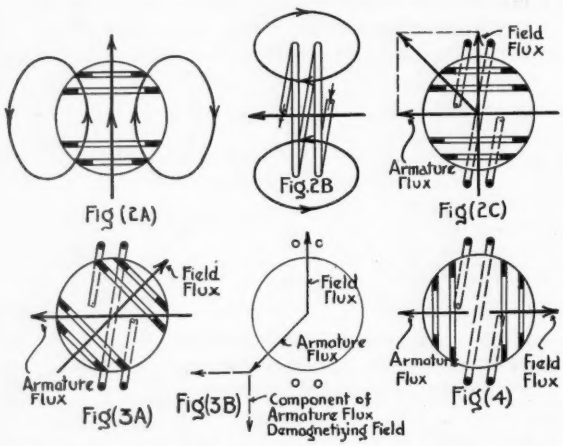
This is not so in practice since the commercial transformer acts to limit the flow of current beyond a certain amount and it does this through what is called leakage reactance. The primary and secondary windings are never quite completely coupled together via the magnetic circuit; some of the flux leaks across between the windings as shown in Fig. 1a, where the two coils are wound on opposite legs of the core, an arrangement permitting considerable leakage flux, much more than obtains in practice. Flux which is not common to both windings gives rise to a counter e.m.f. in the primary which is unaffected by the secondary load impedance. It is much the same as if a separate reactance or choke coil were inserted in the primary circuit as in Fig. 1b. Transformers are thus said to possess reactance in consequence of this leakage flux.

The amount of leakage flux present varies in proportion to the amount of current flowing, consequently

the counter e.m.f. generated by leakage reactance is also proportional to the amount of current flowing, reaching a value equivalent to the supply voltage under short circuit conditions. The value of leakage reactance is expressed in terms of full load power. Assume, for instance, that a transformer possesses a reactance of 5 per cent. Assuming also that it is connected to a generating station of infinite capacity and negligible resistance, then under a dead short circuit on its secondary terminals the current will rise to a value of $100 \div 5 = 20$ times full load. Other values of leakage reactance give different values of short-circuit current and the tendency nowadays is towards higher and higher values for protection in times of trouble.

Generators

Two considerations affect the behavior of alternating current generators under short-circuit conditions, armature reaction and armature reactance, two different things somewhat alike in name and behavior and both limiting the current flow which may ensue.



FIGS. 2—4. DIAGRAMS ILLUSTRATING INTERACTION OF MAGNETIC FIELDS IN AN ALTERNATOR

Let us consider armature reaction first and in doing so it will be convenient for the moment to separate the armature of an alternator from its associated field as in Fig. 2, A and B. Figure 2A represents the revolving field of a turbo-generator with its direct current field windings; it has been assumed as rotating clockwise in direction and with the north pole to the top. Figure 2B represents the conductors of one armature phase and due to field excitation a current has been represented as flowing in the direction indicated by the arrows. Unity power-factor has also been assumed for the moment. This armature current inevitably has a magnetic flux associated with it and this armature reaction field, as we may call it, has a position in space and a direction as shown in the illustration 2B.

Now, superimpose the two structures, armature and field, with their associated magnetic fluxes as shown in Fig. 2C. In the position shown the maximum or peak voltage is generated in the armature conductors. The armature reaction flux and the field excitation flux now no longer exist as two distinct entities but combine and produce a resultant flux having a position in space as indicated. A shift in the actual location of the position of maximum flux with respect to the field axis takes place with a decrease in flux at the leading pole up and a piling up at the trailing tip. The resultant flux distribution is much the same as that occurring in direct current machinery under load, with the same result on voltage generated.

In a polyphase generator each armature phase contributes its quota to the armature reaction, one phase coming into action as its load current rises, the preceding one dying away. This results in a continual shift in armature reaction flux, around the periphery of the armature in synchronism with the rotation of the field but lagging 90 deg. behind its polar axis, for unity power factor load. This of course is only another example of the polyphase rotating field.

With this preliminary explanation in mind, let us see how this armature reaction affects the behavior of an alternator on short-circuit. The current at such times is almost wholly lagging, only the reactance of transmission lines, transformers, etc., serving to limit the current flow, voltage drop due to circuit resistance being comparatively negligible.

As an intermediate step assume an armature current lagging 45 deg. behind its voltage. In Fig. 3A we have a similar set of armature coils and field structure to that shown above. In this case the flux due to armature current is shown at the instant of its maximum value but since this current is lagging behind its voltage, the voltage has already reached its peak value, and the rotating field structure has passed on and now occupies a position 45 deg. in advance of that formerly occupied. In Fig. 3B the field has been moved back through this angle of 45 deg. so that the effect of the lag of armature reaction flux can be further studied. It is easily seen that the reaction flux can be resolved into two components, one at right angles to the field flux, the other in alinement therewith but in opposition thereto. A weakening of the effective field is thus produced, requiring an increase in the amount of excitation required to produce a voltage equal to that formerly obtained.

Assuming now a current lag of 90 deg., such as is nearly obtained under short-circuit conditions, a similar analysis will show that the armature reaction flux becomes wholly de-magnetizing. This condition is represented in Fig. 4, where at the time when the lagging armature current has reached its maximum value the exciting flux has passed 90 deg. beyond the position for maximum voltage in the phase under consideration. Remembering that the armature reaction flux is a constant quantity for constant current and is due to the combination of all three phase-currents in a polyphase generator, and further, that it rotates in space with the revolving field as if fixed to it, it is easily seen that it is at all times for zero power factor in direct opposition to the field flux, weakening it and causing a very considerable reduction in voltage.

The armature current producing armature reaction is, of course, much greater under short-circuit conditions than under full load and the resulting voltage drop is thus intensified.

Incidentally, while we are concerned here only with short-circuit phenomena, it may be well to point out that a leading current produces the opposite effect to a lagging one, in that as the current becomes more and more leading, the armature reaction flux assists

the field, providing an auxiliary source of excitation and at some value of leading phase angle a synchronous generator may even become self-exciting.

Under short-circuit conditions, then, the result of the armature reaction flux is to reduce the net amount of current which may flow. As the current increases in value, the field is weakened, the voltage falls and the current consequently decreases to a constant value, determined by the circuit and machine constants.

Armature Reactance

Armature reactance as distinct from reaction is much the same in its effect as the leakage reactance of a transformer and similarly it is a leakage phenomenon. Under conditions of open circuit, all of the excitation flux leaving the pole face of the rotor can be considered as cutting each and every armature conductor. Under load, however, the individual conductors possess magnetic fields of their own, leading to a rearrangement of the excitation flux distribution. Part of this flux now jumps across from tooth to tooth, returning to the opposite pole without cutting any armature conductors on the way. This slot leakage flux can thus be considered as identical in nature to the leakage flux existing in a transformer under load, for while in one case the excitation is provided by direct current, in the other by alternating current, the effect is exactly the same.

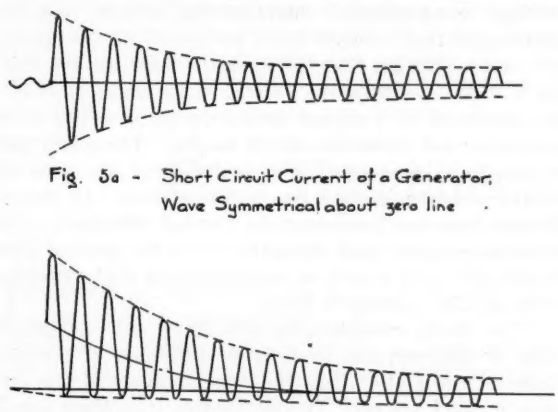


Fig. 5a - Short Circuit Current of a Generator;
Wave Symmetrical about zero line
Fig 5b. Short Circuit Current of a Generator.
Wave totally displaced at instant of
short circuit.

FIG. 5. SHORT CIRCUIT CURRENT DIAGRAMS OF GENERATORS

A further leakage of flux can also exist from tooth tip to rotor to tooth tip again, while the end turns of the armature windings each give rise to a magnetic flux surrounding them and distinct from the main flux paths of the machine. All these are additive in their effect and all serve not only to affect the regulation on load but also to limit the current developed under conditions of short-circuit.

Armature reactance and reaction have slightly different actions in this limitation of current flow. In Fig. 5, a and b, are shown two typical short-circuit current curves of an alternator. Both are seen to start at a comparatively high value and both gradually decrease in amplitude down to a value which gives the steady state current flow. The initial amplitude of the current rush is determined by the machine reactance, just as in a transformer, the decreasing amplitude characteristic is caused by the armature reaction, which, coming into play as the current rises, gradually overcomes the highly inductive field and decreases the excitation until a condition of equilibrium obtains.

It will be noticed that one curve is symmetrical about the zero axis. This type is given when the short-circuit occurs as the machine voltage is passing through a maximum value. If, on the other hand, the short-circuit occurs when the voltage is passing through its zero value, the current will rise to twice the first value and will be totally displaced above or below the zero line. Note that in both cases the amplitude of the current measured between crests is the same. In its effects on apparatus the totally displaced or asymmetric wave, as it is called, is much the worse of the two. Any shape in between these two extremes is possible, depending on the instantaneous voltage at the instant of short-circuit.

Reactive Effects of Other Apparatus

Transmission lines are closed loops with magnetic flux associated with the flow of current. The magnitude of this flux depends on two factors, the area enclosed by the loop or the spacing of the conductors and the amount of current flowing. The spacing of conductors is, of course, a fixed quantity while the current flowing, the magnetic flux and, in consequence, the inevitable e.m.f., vary, the two latter being dependent on the current. Transmission lines thus possess reactance, this reactance being capable of being expressed in terms of some convenient percentage.

Multi-conductor lead-covered power cables also possess reactance, although since the spacing of the conductors is so close, it is usually negligible in amount and is usually counterbalanced by the condenser effect of the adjacent conductors, at least on cables of any appreciable voltage.

Current limiting reactors are examples of a true inductance, choke or reactance coil; the field is concentrated due to the many turns of wire closely spaced, the counter e.m.f. is high and they serve excellently to limit current flow in any system into which they are inserted, this being their principal function.

Whimsicalities of the Telephone

Although the telephone, as an instrument, is more or less standardized the world over, its uses vary greatly and according to the customs of the country. In Abyssinia, as an instance, you must first write your message and hand the written manuscript to the operator, who in turn shouts it into the transmitter, no one else being permitted to use the instrument. In Cuba a widow with several children is always chosen, where possible, as the operator of isolated exchanges, since her children can act as messengers and thereby cut expenses. In Russia it is a penal offense to address the operator in any other way than "Comrade" or "Citizeness," while in Germany, no telephone operator is permitted either to bob her hair or wear jewelry. Even in England the operators are wont to say "You're through" when the connection has been completed and you are ready to begin the conversation.

Grounding Systems for Electric Stations

PART II. GROUNDING REQUIREMENTS FOR DIFFERENT EQUIPMENT, METHODS FOR ARTIFICIAL TREATMENT OF SOIL. BY C. M. RHOADES*

IN OUTLINING the following suggestions for the size of ground connection from various pieces of apparatus to the common ground bus, it is naturally assumed that no connection need be larger than the common ground bus, as this is figured for the maximum current and time that the fault current will flow to ground.

Generators, converters, motors, etc., should have their frames and neutrals grounded with a connection equal in cross section to the power leads, but in no case need this connection be larger than the main ground bus.

Power transformers should have their tanks grounded with a connection equal to the main ground bus.

Oil circuit breakers should have their frames grounded with a copper connection having a current capacity equal to one-fourth of the ampere rating of the oil circuit breaker, but in no case should this connection be smaller than 4/0, nor need it be larger than the ground bus.

Lightning arrester ground connections should be of the same size as the line lead to the arrester.

Potential transformer cases, current transformer bases, disconnecting switch bases and insulator bases when mounted on pipe or angle framework or at the back of switchboards will have their bases grounded through the pipe framework. The pipe framework in turn should be connected to the main ground bus through the equivalent of 1 in. by ⅛-in. copper, one connection to be supplied for every three joints in series, either bolted or clamped.

When potential transformers are mounted in masonry compartments, whether the isolated phase or group arrangement is used, they should have their cases grounded with a copper connection of sufficient size to be mechanically strong. This should be equal in cross section to the primary lead and in no case should be smaller than 1/0.

Current transformers in the case of isolated phase arrangement, should have their feet or enclosing cases grounded with a copper connection equal to the main ground bus.

Disconnecting switches tied to the main bus should, in the case of isolated phase arrangements, have their bases grounded with copper connections equal in cross section to the main ground bus.

Bus insulators should, where a fault bus system is used, have their bases connected to the fault ground bus by a copper connection equal in cross section to this bus.

Where air insulated current transformers, disconnecting switches and insulators, in the case of group arrangement, are mounted directly on masonry and the fault bus system is not used, no provision need be made for grounding the bases or feet. It is recognized that in following out this suggestion there is a possibility of fault currents tending to find a path through the reinforcing steel and structural steel of the building; however, it is thought that the danger is not sufficiently great to justify the expense of grounding the bases or feet of bus insulators, disconnecting switches and current transformers when so mounted.

Building columns or columns of outdoor structures should be connected to the ground bus with a conductor of not less than 1/0 cable and this connection should be made at the base of the columns only.

Cable is recommended for all ground connections, rather than wire, as the latter is more likely to be damaged by settlement or fracturing of concrete in which these ground cables may be imbedded.

GROUNDING OF RODS OR HANDLES OF OUTDOOR DISCONNECTING SWITCHES

In order to protect an operator from insulator leakage, breakdown or flashover when operating a high voltage, gang-operated disconnecting switch, it is recommended that a metal plate be placed on the ground in such a position that the operator must always stand on it when operating the switch. This metal plate is to be connected by a copper conductor at least 4/0 to the operating rod above the switch handle. The metal plate is also to be connected by a conductor of the same size to the common ground bus of the station. In case of leakage over an insulator, the current will have a low resistance copper path from the rod to the ground plate, in parallel with a path of comparatively high resistance through the operator's body.

The above recommendations carry out the general idea of assuring that there is no difference of potential between the plate where the man stands and the common ground system. It also assures that there can be no difference of potential between the man's hands and feet, provided the copper connection between the switch rod and plate is kept intact. It will be necessary so to install this connection and the connection to the common ground bus that they may be easily inspected to see that they are in good condition. It is also understood that the metal structure supporting the disconnecting switch is independently connected by copper cable to the common ground bus.

In some cases it has been proposed to use insulated platforms for the operator to stand on. This is not recommended on account of the difficulty in keeping such platforms insulated, because of grass, moisture, etc.

Insulating the switchrod, i. e., the vertical rod extending from the switch handle up the structure to the switch mechanism, is not recommended on account of the difficulty in keeping this insulation in good condition, and on account of the possible loss of insulating value during rain.

When the switch is mounted on a wooden pole structure, the base of the disconnecting switch should be grounded.

Multiple pipes or rods, even in large number, will sometimes fail to produce an adequately low resistance to earth. This condition will attend installations involving soil of high resistivity. The alternative is to reduce the resistivity of the soil immediately surround-

*Construction Engineering Department, General Electric Co.
Note: The first part of this article was published in the June 1 issue.

ing the driven pipes. To accomplish this, it is necessary to dissolve in the moisture normally contained some substance which is highly conductive in its water solution. There are many such substances, but perhaps those most suitable are sodium chloride (NaCl), calcium chloride ($CaCl_2$), sodium carbonate (Na_2CO_3) and copper sulphate ($CuSO_4$). The sodium chloride, better known as common salt, has perhaps been most generally used.

The important thing in connection with the application of any of these agents for reducing soil resistivity is their liberal use and also the moisture content of the soil. With average or high moisture content these agents form a conducting electrolyte throughout a wide region surrounding the ground electrode. Approximately 90 per cent of the resistance between a driven pipe and earth lies within a circle having a radius of about 6 ft. from the pipe. This may be kept in mind in applying the agents for artificial treatment of soil. The simplest application would seem to be made by excavating a shallow basin around the top of the pipe, perhaps 3 ft. in diameter and a foot or so deep, and applying the artificial agent in this basin. The basin should subsequently be filled with water several times which should be allowed each time to soak into the ground, thus carrying the artificial treatment, in electrolyte form, to greater depths and allowing the artificial agent to become diffused throughout the greater part of the effective cylinder of earth surrounding the driven pipe.

Not a great deal of definite data is to be found on the corrosive effects of these artificial treating agents. Theoretically salt is corrosive, but practically it is doubtful if appreciable reduction in the life of iron pipe would be noticed. This is somewhat substantiated by the serviceability of iron water pipes embedded in salt marshes. One power company claims that copper sulphate is preferable to salt for use around copper electrodes. They state that the $CuSO_4$ has nearly twice the solubility of common salt at ordinary temperatures. It is stated that, with copper sulphate around iron pipes, it was found that the pipe was not eaten away as much as when salt was used. The tendency with the copper sulphate seems to be to deposit copper on the galvanized pipe, which serves to protect it further.

Care should be taken in all cases of artificial treatment where $CuSO_4$ is used to avoid any possible contamination of domestic water supply.

It is recommended that the desired ground resistance be obtained without artificial treatment of the soil, if possible, as the results of such treatment gradually disappear and have to be frequently renewed. In special cases the treatment may be found necessary and desirable.

Coal Handling at Dresser Station

DETAILS OF EQUIPMENT AND METHODS OF HANDLING COAL AND ASH AT THIS MOUTH OF MINE PLANT. BY H. M. SHARP*

DRESSER STATION of the Indiana Electric Corporation is a mouth-of-mine plant located on the Wabash River about 7 mi. southwest of Terre Haute, where the company owns 63 acres of land together with coal rights on over 3000 acres of adjacent territory. It is estimated that the mine now being developed on the company's property will meet the ultimate requirements of the station for the next 30 yr.

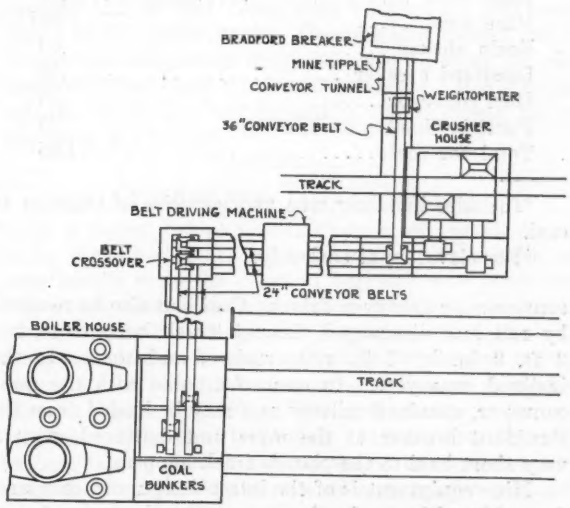
This seam of coal, known as 5th Vein Indiana, is approximately 4 ft. thick and about 225 ft. below the surface. The Indiana Electric Corp. will not do its own mining, but will make a contract for the development and operation of the mine whereby coal will be delivered to the plant conveyors in quantities required at a fixed contract price per ton.

As the mine has been in operation for only a few months it is not yet able to meet all of the requirements of the plant although about 2 mi. of entries have been driven, some of them passing under the river. The mine is remarkably dry and except for the low head room, working conditions are favorable.

Locomotives designed for 250-v. d. c. trolleys are used for mine hauling. Although the trolleys are only a few feet above the floor level, there is little danger of injury to workmen because of the flexible rubber curtains that parallel the trolley and hang several inches below it.

Loaded mine cars are run onto the platform of the 400-hp. hoist, are locked in position and elevated at a speed of 1600 ft. per minute, to the top of the tipple where they are automatically upended to dump into the tipple scales. When operating at full capacity, a mine car will be elevated every 25 sec., giving an 8-hr. capacity of 2500 t. Coal from each mine car is weighed separately and the miners' pay roll computed from these weights. Rock and other mine refuse can be elevated in the regular mine cars and run off on tracks at the surface, or may be elevated to the tipple and discharged through a bypass chute to railway cars.

Coal is dumped from the tipple scale hopper onto a



PLAN OF EQUIPMENT SHOWS ARRANGEMENT OF BREAKERS, CONVEYORS, BUNKERS AND RAILROAD TRACKS

*Tech. Engineer, Indiana Elec. Corp., Terre Haute, Ind.

reciprocating screen shaker where the fines are separated from the lump coal, the former passing directly to a horizontal belt conveyor while the latter passes into a 200-t. per hr., 12 ft. by 17 ft. Bradford breaker to be reduced to a size that will pass through 1¼-in. holes before being discharged to the belt. This single 36-in. belt, 227 ft. between centers, driven at 300 ft. per min., by a 30-hp. motor, is equipped with a 300-t. per hr. weightometer, transports the coal through a tunnel and discharges through a two-way chute to the plant conveyors. A double check on coal weights is obtained from the tipple scales and weightometer.

For the plant conveyor system two 385 ft. long, 24 in. wide, inclined belt conveyors and two short 24-in. cross over conveyors, 185 ft. long, leading to the boiler house bunkers are used. Both the long and short conveyors have an 18 deg. angle, a speed of 300 ft. per minute and the capacity of each 24-in. belt is 100 t. per hr.

Bunkers are divided into four compartments with a combined capacity of 1800 t. Coal is withdrawn from V shaped pockets into either one of two traveling weigh larries which distribute coal to the chain grate stoker hoppers. The larry scales permit a third check on coal weights. Ash is dumped through pneumatically operated gates into standard gage cars for final disposal.

Adequate protection in the form of electrical and mechanical interlocks will prevent piling up of coal at any point of the conveyor system due to failure of conveyors or conveyor drives. Coal can also be received by rail and discharged through track hoppers to two 2 ft. 9 in. by 3 ft. roll crushers and thence to the inclined conveyors. In case of trouble with the mine conveyor, standard railway cars may be loaded from the Bradford breaker at the mine and delivered, with a very short haul to the plant's track hoppers.

Mine equipment is of the latest design and compares favorably with any in the state. The tipple is of steel and concrete construction with a housing of corrugated sheet zinc to resist corrosion.

POWER FOR HANDLING COAL

Equipment	Kw-hr. per Ton of Coal Handled
Mine hoist	.75*
Mine hoist	.52†
Recip. shaker	.03
Bradford breaker	.22
Hor. conveyor	.05
Plant inclined conv.	.23
Total for coal	1.05

*Includes handling men and supplies in addition to coal.

†For elevation of coal only.

ACCORDING TO A RECENT announcement by H. W. Fuller, Vice-President in charge of engineering and construction of Byllesby Engineering & Management Corp., Chicago, the Potomac River Power Corp. has filed application with the Federal Power Commission for a preliminary permit contemplating the development of water power project on the Potomac River. If the project is carried through to completion, a total of 350,000 hp. may be developed.

Rack and Headgates at Cedar Creek Station*

BY W. S. LEE

FOR the Cedar Creek Station of the Duke Power Co., on the Catawba River, provision is made for three 19,000-hp. turbines under 60-ft. head. The penstocks are formed in concrete with racks at the upper end and headgates inside the racks. Location of the parts of the intake is shown in Fig. 1 and rack and headgate positions in Fig. 2.

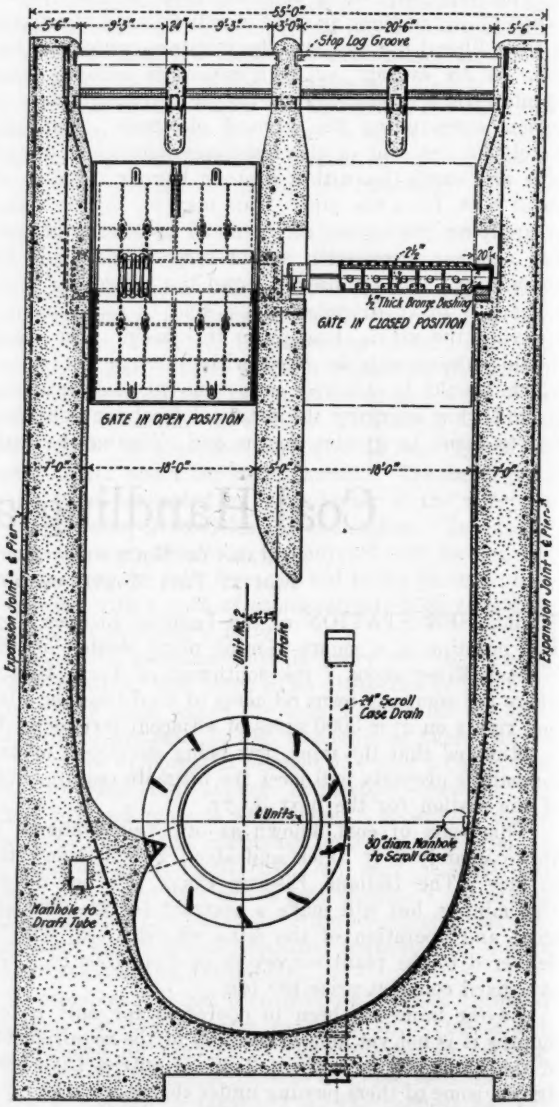


FIG. 1. INTAKES ARE OF CONCRETE CARRYING STOP LOGS, RACKS, HEADGATES AND WHEEL CHAMBER

Each wheel has four racks made up of steel bars, 6 in. wide, ⅜ in. thick and spaced 4½ in. on centers, the bars being held in slotted angle irons at the top, center and bottom. Details are shown in Fig. 3. Velocity of the water through the racks is 2.5 ft. per sec.

*From a paper presented before the A. S. M. E. at White Sulphur Springs, May 23-26.

at 0.9 gate opening with discharge of 2970 cu. ft. per sec. Structural frames were riveted up at the manufacturer's works; rack bars were shipped in bundles and inserted at the plant. Above the racks, stop log grooves are provided so that the penstock can be unwatered for inspection and repairs.

Each gate, as shown in Fig. 2, is made up of a steel girder, which carries the trunnions, and two cast-iron wings, held to the girder by shrink links and steel bolts. The girders are 3 ft. in depth and 2 ft. 8 in. wide with bronze-bushed trunnions, 2 ft. 4 in. diameter by 20 in. long. Gates are 17 ft. 9 in. wide by 24 ft. 9 in. high. At the bottom, the gate swings down against bevels on the cast-iron frame, while at the top, seal is

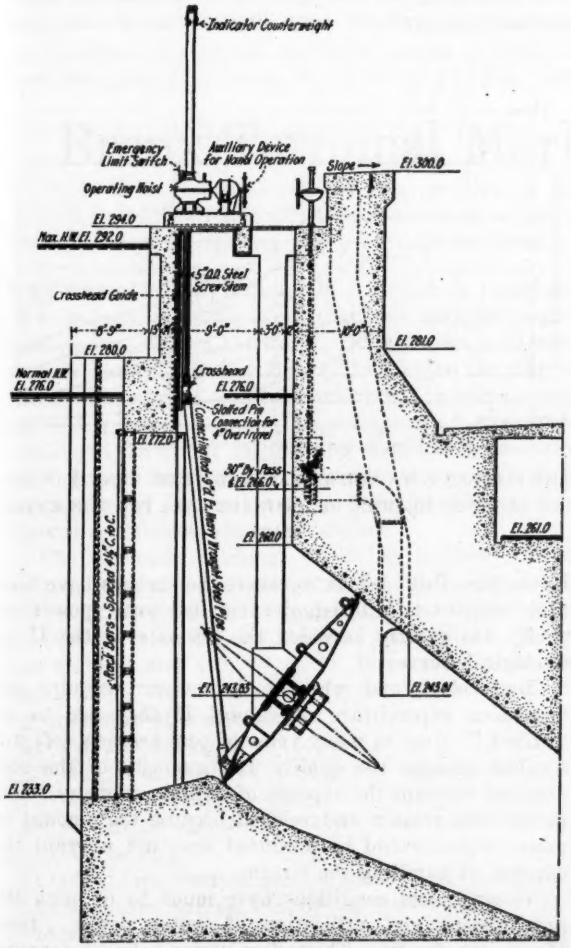


FIG. 2. GATES ARE OF BUTTERFLY TYPE OPERATED BY MOTORS ON THE RUNWAY ABOVE

made by bronze seal springs attached to the framework. Operation is by a connecting rod joined to the gate and to the crosshead by steel pins 4½ in. diameter. The lower pin works in bronze bushings, while the upper end of the rod is slotted to allow 4 in. overtravel of the crosshead.

The crosshead is moved by a vertical screw which, in turn, is actuated by a revolving nut, driven by an electric motor, located well above high water level. Auxiliary hand operation is secured by a wheel on the motor shaft. By a nest of heavy coiled springs, breakage of the mechanism, in case the down limit switch fails to operate, is avoided, the springs operating an overload release switch. The gate is overbalanced downward by means of concrete in the lower wing, so that it will close by gravity in case the operating mechanism becomes disconnected. Control of the motor is by push button from the runway above the gate but emergency

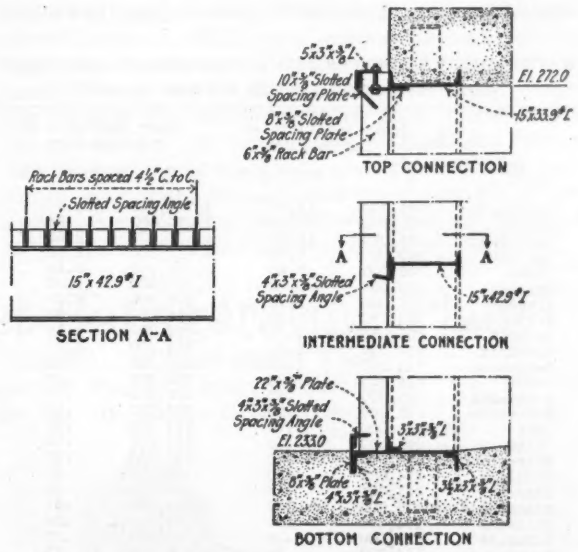


FIG. 3. RACKS ARE OF STEEL BARS HELD IN SLOTTED ANGLE IRONS ATTACHED TO A STRUCTURAL FRAMEWORK

control can be had from push buttons on the bench board in the power house. Opening and closing are in 8 min. the mechanism being designed to close the gate under full head and volume of discharge. For starting up, the intake is filled through a 30-in. bypass before the gates are opened.

Condenser Tube Erosion

IN A PAPER before the Institution of Naval Architects, Sir Charles A. Parsons relates the results of experiments as to the effect of turbulence in the water box of a surface condenser on the erosion of the inside of tubes near the inlet end. Vortices were formed by the turbulence and, when one of these vortices moved over the inlet to a tube, it was found to slow down discharge through that tube. While results are so far not conclusive, they tend to confirm the view that the turbulence is one of the chief causes of tube erosion and suggestion was made that, by enlarging inlet passages to the water box so as to reduce velocity before entering, or by placing a grid in front of the tubes with passages of depth greater than their width, turbulence at the entrance to tubes would be avoided and erosion mitigated if not prevented.

A DUTCH ENGINEER, Professor Dijkshoorn, has recently discovered an effective method of removing the last traces of oil from steam-engine condenser water that has been subjected to gravity settling treatment. As reported in a recent issue of the Engineer of London, he filters through a layer of freshly precipitated aluminum hydroxide.

Middle Western Water Power Developments

DEVELOPMENT OF SMALL HYDROELECTRIC PLANTS IN THE MIDDLE WEST DEPENDS LARGELY UPON THEIR ABILITY TO CARRY PEAK LOADS ON A LARGER SYSTEM. BY FLOYD A. NAGLER*

WATER POWER resources are difficult to estimate accurately, although the U. S. Geological Survey recently completed an estimate for the various states. These figures are given for 30 states showing the amount of power available and, in addition, the amount of power installed and the development as a percentage of the power available at medium flow.

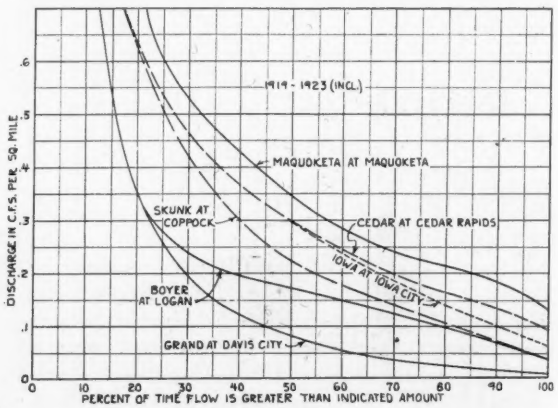
Most of the potential water power of the nation lies near its borders, so that, on account of its relative scarcity in the Mississippi Valley where good grades of fuel are not plentiful, a unit of water power in the middle west would tend to be more valuable than the same amount on the coast. The middle west, however, is somewhat handicapped geographically because of limited storage area. With ample pondage it has proven economical to develop the natural streams beyond that flow which is available one-half the time, in some cases even exceeding the average flow of the stream which generally is available only 30 per cent of the time.

WATER POWER RESOURCES AND INSTALLED CAPACITY SHOW GREAT VARIATION IN THE SEVERAL STATES

STATE	Power Available at Median Flow H P.	% TOTAL U.S.	Power Available at Minimum Flow H P.	% TOTAL U.S.
Washington	7,871,000	14.30	4,970,000	14.27
Oregon	6,715,000	12.20	3,665,000	10.53
California	6,674,000	12.13	4,603,000	13.22
New York	4,960,000	9.03	4,010,000	11.52
Idaho	4,032,000	7.33	2,122,000	6.10
Montana	3,700,000	6.72	2,550,000	7.32
Alabama	1,050,000	1.91	472,000	1.35
W.Virginia	980,000	1.78	355,000	1.02
Georgia	958,000	1.74	572,000	1.65
Virginia	812,000	1.48	459,000	1.32
Tennessee	710,000	1.29	432,000	1.24
Texas	514,000	.94	238,000	.69
Wisconsin	480,000	.87	285,000	.82
Minnesota	401,000	.73	203,000	.58
Iowa	395,000	.72	169,000	.49
Illinois	361,000	.66	189,000	.54
Nebraska	342,000	.62	183,000	.53
Michigan	274,000	.50	168,000	.48
Kansas	251,000	.46	104,000	.30
Massachusetts	235,000	.43	106,000	.31
Oklahoma	194,000	.35	70,000	.20
N.Dakota	193,000	.35	82,000	.23
New Mexico	186,000	.34	116,000	.33
Kentucky	184,000	.33	77,000	.22
Arkansas	178,000	.32	125,000	.36
Ohio	166,000	.30	55,000	.16
Missouri	152,000	.27	67,000	.19
S.Dakota	110,000	.20	63,000	.18
Indiana	110,000	.20	40,000	.12
Louisiana	2,000	.00	1,000	.00

INSTALLED WATER WHEELS

STATE	H P.	% AVAILABLE AT MEDIAN FLOW
Massachusetts	353,939	149.5
Michigan	355,261	129.7
Wisconsin	473,976	98.7
Minnesota	274,589	68.4
Alabama	659,208	62.8
Indiana	56,156	51.0
Iowa	186,591	47.3
Georgia	448,670	46.8
New York	1,757,355	35.4
California	1,916,980	28.7
Illinois	94,202	26.1
Tennessee	174,175	24.5
Kentucky	34,255	18.6
Ohio	30,320	18.2
S.Dakota	19,671	17.9
Virginia	138,046	17.0
Maryland	39,225	16.5
Missouri	20,560	13.5
Montana	376,040	10.2
W.Virginia	91,279	9.3
Arkansas	15,550	8.7
Washington	656,722	8.3
Idaho	320,097	7.9
Kansas	16,914	6.8
Nebraska	21,335	6.2
Colorado	95,554	6.1
Oregon	241,759	3.6
Nevada	13,450	3.6
Texas	14,835	2.9
Arizona	59,360	2.1
New Mexico	1,808	1.0
Wyoming	10,480	.9
Oklahoma	1,948	.1
N.Dakota	245	.1
Mississippi	000	0
Louisiana	000	0



THE FLOW IN IOWA STREAMS AVERAGES LESS THAN 1 CU. FT. PER SEC. PER SQ. MILE OF DRAINAGE AREA FOR THE ENTIRE YEAR

In the New England states, where the streams have been more completely utilized, the installed water power capacity has greatly exceeded the estimate of the U. S. Geological Survey.

Both black and white coal, however, require the hazardous expenditure of capital if they are to be "mined." Just as many veins of coal are now left untouched because the quality and quantity of the coal does not warrant the expense of mining, so many water power sites remain undeveloped because the amount of power which would be produced does not warrant the expense of handling the stream.

Geographical conditions have much to do with the development and utilization of water power. Iowa Rivers are erratic. Their flow varies between torrents during the heavy rains and a scarcity of water in the dry season. The flow cannot be depended upon and the power generated varies from day to day. As such this power is not valuable unless the flow could be well regulated by natural or artificial storage.

GEOGRAPHIC CONDITIONS IN MIDDLE WEST ARE NOT AS GOOD AS IN EAST

Of the 33 in. of rain which fall in an average year on the drainage area on an Iowa stream, only 7 in. reaches the stream and is available for water power, while in New England over 20 in. of the 40 in. of annual rainfall reaches the rivers. Other factors being the same, an Iowa stream draining a given area has only

*Associate Prof. Mechanics & Hydraulics, University of Iowa. From a paper presented before the Iowa Power Conference.

one-half to one-third the flow of a stream in the east draining the same area.

There is also a marked difference in the discharge of various streams in the state itself, due largely to a decrease of nearly 10 in. in average annual rainfall which exists as one passes from the northeast to the northwest corner of the state. Large variations shown by some of the rivers appear in the illustration. Even various branches of the same stream may show widely different characteristics.

Channels of Iowa streams fall between 1 and 8 ft. per mile. This drop is moderate indeed and limits the developments to comparatively low head plants. Only 20 per cent of the water power plants of Iowa develop heads of more than 15 ft. and 50 per cent of them operate on heads less than 10 ft. The capacity for storage of water during the low water season in order to meet the peak of demand for power is limited. Low head plants have the further disadvantage of having the head reduced greatly during times of floods, the fall over the dams being increased to such an extent that it is impossible to generate power.

It is to be expected that the future development of small power will be accomplished by building a large number of small, low and average head plants. Such plants cannot be operated with profit but may be economical when interconnected by transmission lines into large electric systems. With such intercommunications during times of low water, it is generally found most economical to operate the steam plant on base load, carrying the peak with the hydroelectric plant. This insures the operation of the steam plant at high load factors and reduces the steam plant investment. Power generated with water then becomes more valuable to the system than the cost of the fuel which has been replaced by the kw-hr. output of the hydro-electric plant.

Bronx Terminal Market Refrigerating Plant

MUNICIPAL PROJECT OF CITY OF NEW YORK WILL BE COMPLETED IN EARLY FALL, AND WILL BE SERVED BY A REFRIGERATING PLANT, ALREADY INSTALLED, HAVING MANY INTERESTING DESIGN FEATURES. BY AUSTIN C. LESCARBOURA

WHEN ITS NEW municipal market is completed in early fall, New York City will have the largest municipal market in the world. This project is situated on a 38-acre tract in The Bronx, abutting on the Harlem River; it comprises a storage building, a wholesale market and a power house. The refrigerating equipment considered from an engineering standpoint, contains some unusual features, but even were these wholly lacking, the size of the market as a whole and of the various units it contains would be of interest.

The wholesale building, which has facilities for receiving, storing and disposing of foodstuffs, has 2,233,000 cu. ft. available for storage purposes. Of this total, 675,000 cu. ft. is for dry storage; 1,093,000 cu. ft. for cold storage, and 465,000 cu. ft. for eggs. In the following table, the storage capacity is expressed in varying quantities of foodstuffs:

124,000 cases of eggs
1,620,000 lb. of poultry
3,720,000 lb. of butter
650,000 lb. of cheese
1,620,000 lb. of beef
119,000 boxes, barrels, etc., of fruit
119,800 boxes, barrels, etc., of vegetables
18,600 cu. ft. in 36 stalls for miscellaneous merchandise.

The new market is served directly by the New York Central Railroad, which enters the wholesale building. Immediately to the south of the market, the Erie Railroad is constructing a terminal for expediting the movement of foodstuffs handled by that line. For the convenience of users of western railroads terminating in Jersey City, shipments are to be transferred from that point by means of floats, which will be accommodated at docks and piers now under construction on a one-half mile stretch of waterfront property acquired by the city.

Mechanical, electrical and refrigerating equipment of the new municipal market were designed by Major George F. Hill, who, during the past twenty-five years, has specialized in the design and installation of steam and electric power plants and in refrigeration and ice-making machinery.

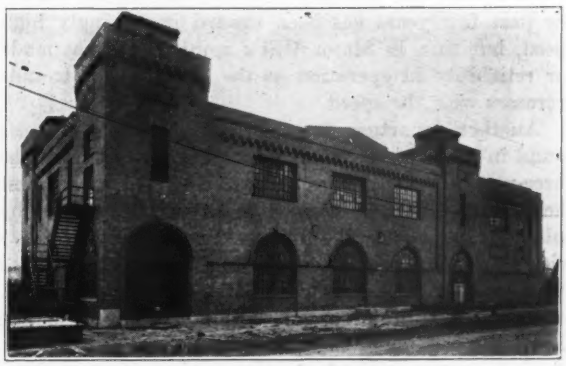


FIG. 1. REFRIGERATION EQUIPMENT IS INSTALLED IN THIS POWER HOUSE SEPARATE FROM MAIN BUILDINGS

PLANT HAS REFRIGERATING CAPACITY OF 1035 T.

The plant is equipped with seven ammonia compressor units. Four of these are each capable of producing 200 t. of refrigeration a day. Two others have a daily capacity of 100 t., while the seventh unit, which is a pump-out machine, has a capacity of 35 t. An interesting feature is the ease with which all compressors, circulation pumps and coolers can be operated on either the high or low temperature systems. In high temperature operation, with the brine at 10 deg. F., the compressors operate at 15 lb. back pressure and 185 lb. head pressure. In low temperature operation, with the brine at —10 deg. F., the back pressure is 3 lb. and the head pressure 185 lb. The oil circulating around the ammonia piston rods is cooled by an oil chamber surrounding the ammonia suction pipe. Contrary to usual practice, the ammonia compressor frames are not cast as

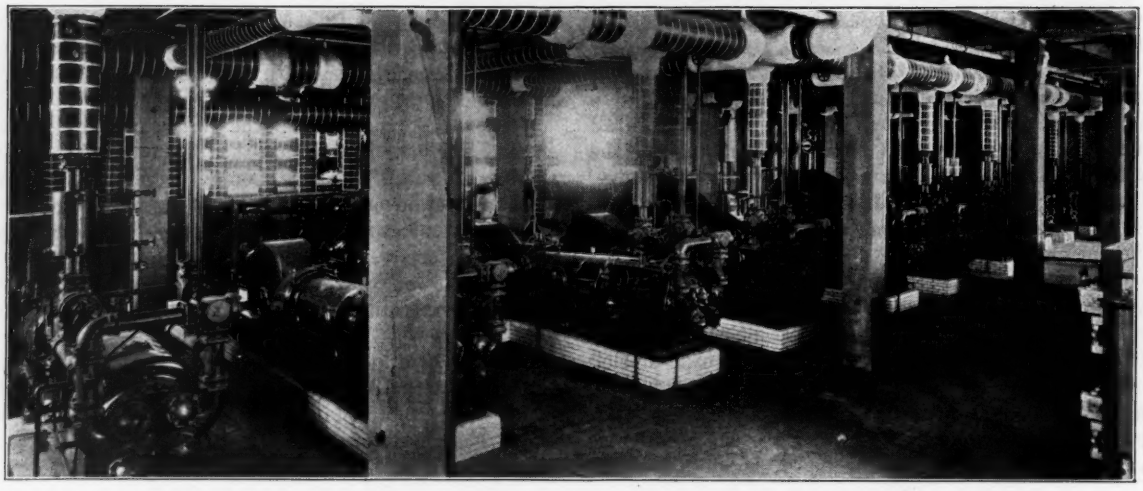


FIG. 2. SEVEN MOTOR-DRIVEN AMMONIA COMPRESSORS CAN BE OPERATED ON EITHER THE HIGH OR THE LOW TEMPERATURE SYSTEMS

units, but are in bolted sections. In the design of these compressors, Major Hill has specified a maximum speed of 109 r.p.m. The tendency in compressor design during the past few years has been toward increasingly high speed, but this, in Major Hill's opinion, has not made for reliability in operation as the likelihood of trouble increases with the speed.

Another departure from standard practice is to be found in the brine distributing mains. These are of the three-pipe balance system and are designed to decrease the head pressure on the brine circulating pumps by balancing the load. The pipe used is 10-in. extra heavy with Van Stone joints and is connected to an insulated surge tank on the roof of the wholesale building.

To insure uninterrupted service, two water suction lines, each capable of supplying from 2,000 to 4,000 gal. of river water a minute to the condensers, have been provided. In a plant the size of the new Bronx Municipal Terminal Market, a shut-down for an 8 or 10-hr. period would be a disastrous matter. With two independent lines, however, the possibility of debris accumulating in the foot valves in the suction wells and thus causing a suspension of operation is obviated. The dual intake system facilitates inspection and cleaning and makes it an easy matter for the engineer on watch to switch from one suction line to the other in the event of a failure in the water supply. The water is drawn from the Harlem River at about 74 deg.

Bronze Pumps Needed to Handle Harlem River Water

Owing to a peculiarity of the Harlem River water, probably due to the presence of sewage, the two horizontal, split-case, double-suction volute centrifugal pumps used in connection with the intake lines, have been designed with solid bronze casings. Experience has shown that where cast iron casings are employed with this water, deterioration occurs within a year or so. In the meanwhile the casing has assumed a curious chalk-like consistency and can readily be cut with a knife.

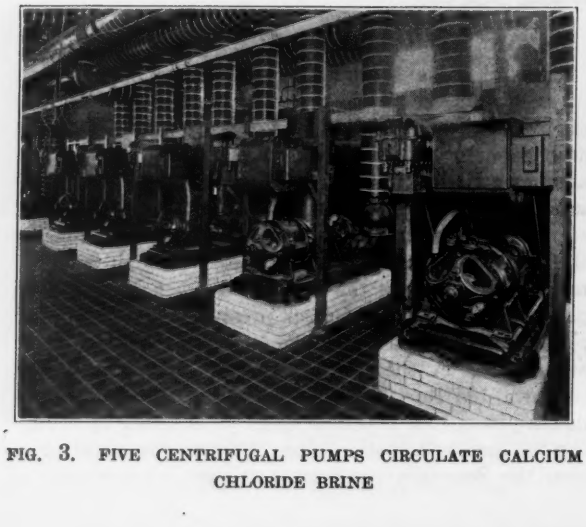


FIG. 3. FIVE CENTRIFUGAL PUMPS CIRCULATE CALCIUM CHLORIDE BRINE

FIG. 4. EIGHT AMMONIA CONDENSERS, OF SPECIAL CONSTRUCTION, ARE SET IN BATTERY WITH LIQUID RECEIVERS IN FRONT

Pumps are also fitted with bronze impellers, bronze renewable labyrinth ring type casing and impeller wearing rings, bronze covered steel shafts, with extended base plates with flexible couplings for connection to 50-hp., 40-deg., 3-phase, 60-cycle, 440-v., 1750-r.p.m. induction motors. These units each have a capacity of 2000 gal. of river water a minute against 60-ft. head. In addition to these units, there is also a smaller pump, having a capacity of 750 g.p.m. against 60-ft. head operating at 1750 r.p.m.

The dry vacuum pump is of the horizontal duplex type, driven by belt from a motor. This unit has a capacity of 80 cu. ft. of air a minute, operating at 200 r.p.m. The pump is connected to the suction header of river water and on the suction line there is provided an inclosed round tank, 24 in. outside diameter and 60

Eight ammonia condensers are of special construction in respect to the heads, spacing of tubes and thickness of shell for insuring ample margin of safety. To obviate the possibility of leakage, Major Hill, after a good deal of investigation, specified that the bridges between tubes be a minimum of ¾ in. The shell is made of two courses of plate, each ⅞-in. boiler flange steel. The longitudinal seams are of triple-riveted double-butt strap construction, with the edges of the seam electrically welded. Each tube head is 1½ in. thick, the upper head supporting the outer distributing chamber being 60 in. in diameter, the lower head being 58 in. square. The condenser tubes at the top are provided with a serrated water distributing ferrule. Tubes are expanded in tube openings and beaded on the outside, each condenser resting on a heavy support.

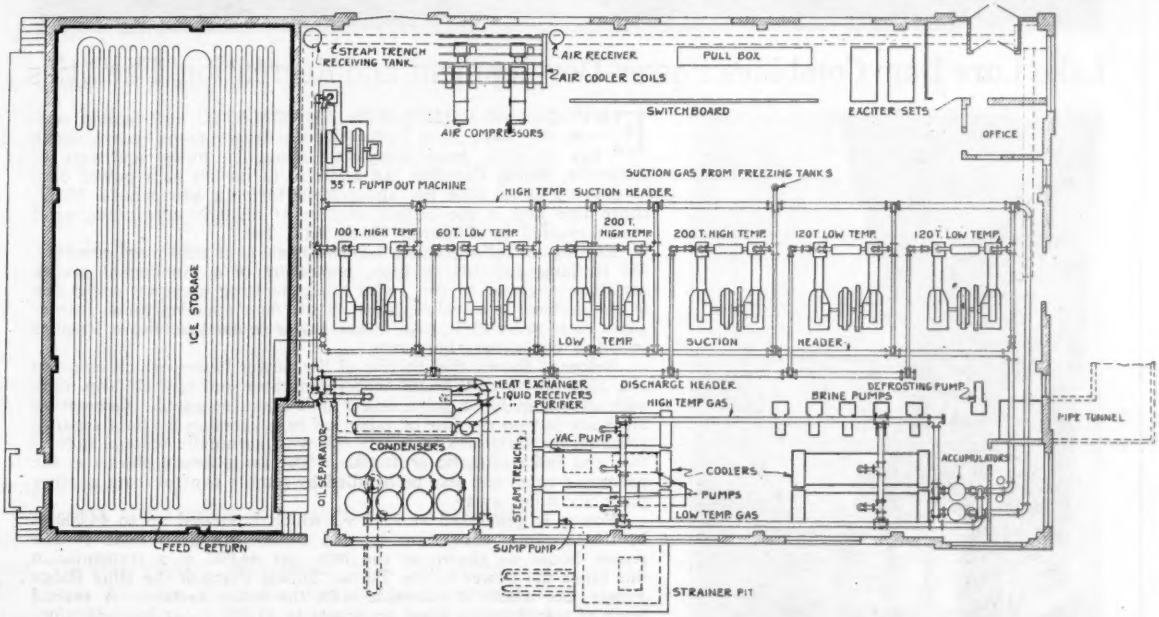


FIG. 5. PLAN OF FIRST FLOOR OF REFRIGERATION POWER HOUSE, SHOWING PRINCIPAL EQUIPMENT AND PIPING. FREEZING TANK IS ON THE SECOND FLOOR DIRECTLY OVERHEAD

in. high, resting on flanged pipe stands. The tank is fitted with a float for control of the motor on the pump and is arranged to shut off the pump when the water reaches a predetermined level, thus obviating the possibility of water entering the pump.

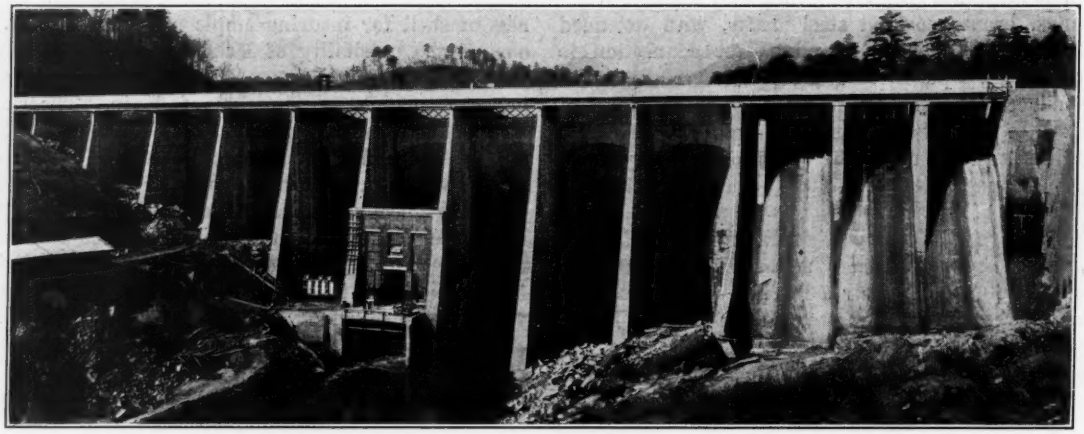
There are five brine circulating pumps. These are of similar type to those on the water intake lines, except that the casings are cast-iron. They are driven by 50-hp. motors. Each unit has a capacity of 750 g.p.m. of calcium chloride brine, specific gravity 1.2, against 100 ft. total head, operating at 1750 r.p.m. The defrosting pump, similar in type, can handle 150 gal. of brine a minute.

The sump pump is suspended from a cast iron plate, located over the sump pit. The motor, a ½-hp., 3-phase, 440-v. induction unit with automatic controlling equipment, is bolted to a cast iron support which in turn is rigidly bolted to the upper side of the pit cover. The pump has a capacity of 40 gal. per min. against a 10-ft. head. The discharge line of the pump, a galvanized pipe, runs to the ammonia condenser pan.

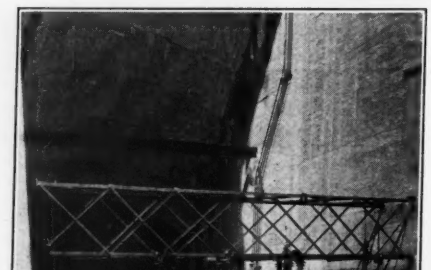
Brine coolers, of which there are five, are of the horizontal shell tubular multi-pass type. The shell where the head is attached is of special construction to provide for expansion and contraction. There are two accumulators, 48 in. inside diameter by 10 ft. high, in connection with the brine cooling system.

The two freezing tanks are of ¼-in. steel, 97 ft. long, 25 ft. 6 in. wide, and 4 ft. high. In each tank there is 20,000 ft. of evaporating pipe. The coils, 10 pipes high, are arranged at each side of the tank and at each side of the bulkhead. The general practice in coil design is to utilize a central valve for the coils. In this installation, however, the coils in all storage rooms are provided with valves on the inlet of each coil, thus making for flexibility of control. The ice making capacity of the plant is 120 t. daily for use in hospitals, for charity and for other purposes.

In the power house there are four step-down transformers, designed to reduce the incoming voltage from 13,200 to 440. Two other transformers, reduce an input at 3200 v. to 210 v.



Lake Lure Dam Combines Power Development and Recreation Facilities

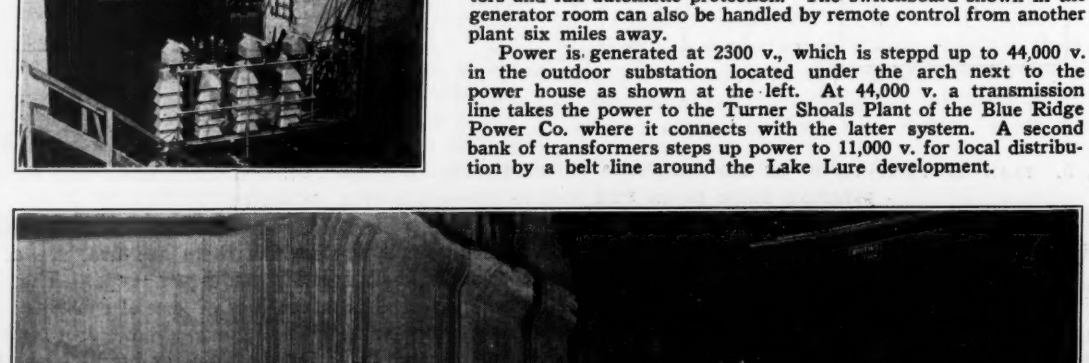


EMPLOYING COMPLETE AUTOMATIC and remote control, the Lake Lure hydro-electric development shown above has recently been completed about 26 miles southeast of Asheville, North Carolina. In addition to its use as a power dam to develop about 5200 hp., the project forms a lake with a 30-mi. shore line and is the central feature of an 8500-acre playground resort created by Chimney Rock Mts., Inc.

Resting on solid granite, the dam itself is of reinforced concrete, 585 ft. long and 104 ft. high, consisting of a number of arches set at an angle of 45 deg., with the generating plant set under one of the arches. A traveling hoist on the dam operates three Tainter gates each 16 by 25 ft. An intake tower in the lake above supplies water to the generating units.

Below is shown the interior of the power house, which contains one 3500-hp. vertical water wheel generator and one 1750-hp. unit, with provision for a third larger unit when required. Generating units are put on the line or taken off in succession by float control, actuated by variations in lake level, with automatic voltage regulators and full automatic protection. The switchboard shown in the generator room can also be handled by remote control from another plant six miles away.

Power is generated at 2300 v., which is steppd up to 44,000 v. in the outdoor substation located under the arch next to the power house as shown at the left. At 44,000 v. a transmission line takes the power to the Turner Shoals Plant of the Blue Ridge Power Co. where it connects with the latter system. A second bank of transformers steps up power to 11,000 v. for local distribution by a belt line around the Lake Lure development.



Locating Grounded Coil in Alternator

To LOCATE a grounded coil in an alternator without disconnecting any of the coils, the test outlined here was employed by the writer recently. A 400-kv.a., 2200-v., 3-phase generator developed a ground of which there was no visible indication but which caused disturbance in a radio receiver in the vicinity. To determine the point of failure an ungrounded 110-v. alternating current source of supply was connected directly to the terminal and frame for a ground, each phase terminal being tested separately and the one giving the highest reading on an ammeter in the circuit was the one which had the ground in its circuit. One terminal of a 110-v. voltmeter was next grounded to the frame of the alternator while the other terminal was connected to an ordinary shoemaker's awl. The sharp point of this awl was used to pierce the insulation on the end connections of each coil in the grounded phase. Connection was made with each coil successively and the voltmeter reading noted in each case. The coil showing the smallest reading was the damaged coil, but the voltmeter readings on three of the coils were so low that it was difficult to determine which one of these three coils was the damaged one.

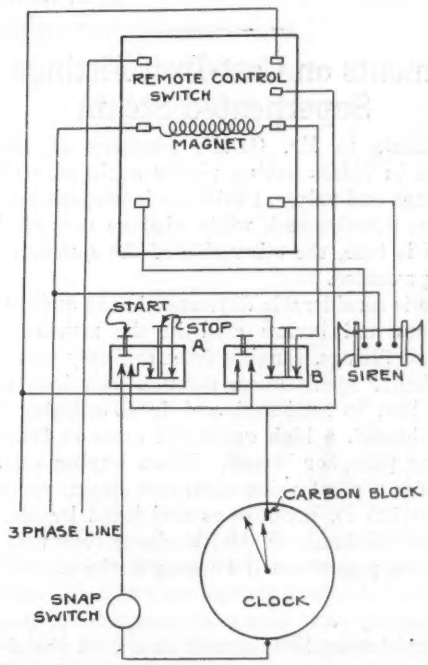
To locate the trouble more definitely, an ordinary telephone receiver was substituted in place of the voltmeter. When contact was made with the grounded coil, there was no noise in the telephone receiver, When contact was made with the coils on either side of the grounded coil, the noise in the telephone could be heard several feet away, consequently it was very easy to find the exact location of the damaged coil and remove it without disturbing much of the other windings.

Elk City, Okla. HARRY J. ACHEE.

Signaling Controlled Semi-Automatically

IN OPERATING starting and stopping signals in a plant by hand it was found that too much of the operating engineer's attention was required so a simple device was developed to operate the siren, used for signaling purposes, in connection with the time clock. The simplest way of doing this was to arrange the clock to close a circuit by means of the minute hand at the 12 o'clock position and have a snap switch in the circuit to avoid sounding the siren except on the desired hours which are usually 7 a. m., 12 noon, 1 p. m. and 6 p. m.

Any time after 6 a. m., for example, the engineer may close the snap switch and at 7 a. m. the minute hand will complete the circuit through a remote control switch, as shown in the illustration, thus causing the siren to sound. Contact is accomplished by attaching a small block of carbon to the inside of the glass door of the clock at a point just in front of the 12 o'clock position, so that the minute hand alone can touch it. This block is beveled so as to allow the minute hand to pass under it without catching and it is such a height that only a light grazing contact is made so as not to interfere with the running of the clock. For this reason also the material selected for the contact block was carbon. The carbon block is connected, as shown, to one of the wires leading to one of the contact points under the starting push button of the control stations. The other contact point under the same button is connected through a snap switch to the metal frame of the clock works. The snap switch is located inside of the cabinet containing the control panel to avoid mistaking it for a lighting switch. The snap switch is then opened after which the remote control can be opened by pressing a push button switch in the circuit of the magnet which holds the remote control closed. This gives the engineer any time within an hour to attend to the siren instead of requiring him to be at the switch at the exact time at which it is closed. The siren is sounded for about 15 sec.



WIRING CONNECTIONS SHOWING HOW CLOCK CAUSES SIREN TO SOUND AT DEFINITE TIMES BY MEANS OF ELECTRICAL CONNECTION

Originally the siren was installed for fire alarm purposes, the remote control switch being located in the power plant and controlled by two push button stations. One of these stations is located in the telephone office downtown, while the other is mounted on top of the cabinet containing the remote control switch at which also the clock is located.

We have been using this system for the past four years. It has proven to be of much help to our engineers. It does not cause any interference with the fire alarm, as the clock circuit is always open except for about 10 sec. while the minute hand is sliding under the contact. The hour hand takes no part in any of the operations except to close the circuit. The entire cost was only 35 cents for the switch and the little wire used. It required only about 1 hr. to construct the entire arrangement. Correct time is checked at noon each day through a radio station.

Pine Bluffs, Wyo. E. H. HARVEY.

Comments on Cast-Iron Fittings for Superheated Steam

REFERRING to Mr. Grief's advocacy of moderate superheat in plants having piping equipped with cast-iron fittings and valves, I think he is proposing a rather dangerous practice and, while what he says of the advantages is true, the other side of the question should also be presented.

There is considerable difference in the quality of the iron, brass and bronze used in the manufacture of valves and fittings, ranging from ordinary cast iron of no particular specification through gun iron and air furnace iron to semi-steel and from ordinary "steam metal" through a high grade red brass to bronzes approaching phosphor bronze. When buying valves and fittings for a plant using saturated steam, particularly at 100 to 125 lb. pressure as mentioned by Mr. Grief, the master-mechanic or chief engineer feels that he has taken extra precaution if he goes to the trouble to get extra heavy standard fittings, etc., without making any special inquiry as to their exact composition, and, under the circumstances, he is correct as a good visual inspection and final test for tightness will show that they are all right and further expense would not be justified.

When, however, the temperature is increased 100 deg. more by the addition of superheat, the expansion is increased about ⅓, since it is now due to a 400-deg. instead of a 300-deg. rise above atmospheric temperature and this will cause a ⅓ or more increase in expansion stresses if the piping is not laid out with ample provision for expansion. The poorer grade brasses lose zinc and become chalky at these temperatures so that more or less trouble may be expected, particularly with small valves, and at times with stems and discs of larger valves.

All this would not be so bad if accurate superheat temperature regulation could be maintained but the average plant which is being modified does not usually have the space available or the money to spend for the combination of convection and radiant heat superheaters, which central station practice seems to show is necessary for accurately controlled superheat temperature. With average boiler control practice, particularly with irregular feeding, superheat temperature fluctuates ± 30 or 40 deg. F. and at times, due to sudden load changes, particularly if a heavy load is dropped suddenly before the fire can be checked, the superheat may rise 50 or 60 deg. so that, while the average temperature may hold around the safe working point, it is often exceeded. These temperature fluctuations, much larger than those due to pressure fluctuations, produce alternating stresses which eventually result in fatigue of metals and failures, even when the periodic overheating does not cause "growth" and weakening of the cast iron sometimes observed.

I can agree heartily with Mr. Grief on the subject of cylinder oil as I worked for several years in one of the early stations operating Corliss engines on steam at 160 lb. gage and 480 to 500 deg. temperature without any difficulty in lubrication of either valves or cylinders but it was only due to a merciful Providence that no one was killed in the steam line failures, as several large cast-iron fittings broke in service and all were ultimately replaced with steel castings. In this case the piping was exceptionally well laid out with duplicate mains, ample provision for expansion and sectionalizing and shutoff valves arranged so that boiler room valves could be operated from the engine room side of the wall and the engine room valves from the boiler room side.

Even one experience of this sort is enough to make a man cautious about a repetition, so the writer feels that anyone considering such a change should also consider the possibility of failure and the losses due to such an interruption of production, besides possible loss of life, and balance this cost against the cost of replacing all important valves and fittings with those made of a material suitable for high temperature.

New Haven, Conn. H. D. FISHER.

Comments on Proper Water Treatment

THE WRITER just finished reading with a great deal of interest the article in your May 1 issue entitled, "Factors Bearing on Proper Water Treatment" by D. C. Carmichael. This article was scientific and exceedingly instructive. In his handling of plant No. 2, however, he has overlooked the advantage of using an alkaline coagulant instead of an acid coagulant to reduce the concentration of soluble salts which in turn would reduce the amount of blow down required.

Mr. Carmichael says he uses ferrous sulphate as a coagulant, but this is an acid salt and forms calcium sulphate when used in the softening plant and requires additional soda ash to convert this to sodium sulphate, thereby increasing the soluble salt content of the treated water. The alkaline coagulant which I have in mind is sodium aluminate. This chemical will not only give better coagulation than ferrous sulphate, but will actually soften the water at the same time instead of hardening as the sulphate does and in addition do this service without adding any extra soluble salt to the water whatever.

Chicago, Ill. H. A. KERN.

THE WRITER agrees with Mr. Kern as to the increase of soluble content of the treated water due to the increase of sodium sulphate through the use of ferrous sulphate. The water in this particular plant, however,

was very high in temporary hardness and low in sulphates as well as limited in the reaction time within the existing softener. In order to decrease the amount of precipitated suspended matter within the limited time given the writer felt it necessary to use caustic soda in excess in place of lime-soda ash combination. A fairly high soda content was, therefore, carried in the treated water which in turn required the addition of sufficient sodium sulphate to maintain the sodium sulphate to soda relation in order to guard against caustic embrittlement.

To prevent the condition described under the term "caustic embrittlement," a definite relation should exist between the sodium sulphate and total alkalinity within the concentrated boiler water. This relation has been recommended by the sub-committee of the A. S. M. E. Boiler Code, which further recommends that this relation be increased with increased pressures. On account of the necessity of using sodium sulphate, the writer felt that ferrous sulphate would have a two-fold effect, namely introducing a settling agent as well as increasing the sulphate content which would necessarily decrease the amount of sodium sulphate used.

As to the formation of calcium sulphate with the use of ferrous sulphate or, in other words, a direct conversion of the acid radical to calcium sulphate is a reaction which may or may not form, depending upon the point of introducing the ferrous sulphate. At this plant, the addition of both the caustic soda and the ferrous sulphate is almost instantaneous, thus the writer feels that there was no calcium sulphate formed, but a direct conversion to sodium sulphate when the ferrous hydrate was precipitated.

Pittsburgh, Pa. D. C. CARMICHAEL.

Filing vs. Piling

MUCH has been written about the merits of filing and the objections to establishing a file. It is a fact, however, that the file has many advantages over the pile. I have been keeping back numbers of Power Plant Engineering for several years and had accumulated such a large pile of these and other magazines that the need for an addition to my house or a condensation of material was inevitable. There was such a vast store of knowledge here that it was out of the question to destroy them, so I decided to file all of those articles that were of particular interest to me. I therefore removed them from the magazines and filed them. Now I have a reference that is exceedingly valuable and can be kept up to date.

On the first index sheet I laid out a general classification, spacing the headings such as Electric Machinery, Boilers, General, etc., about 3 in. apart. Each heading was followed by a letter such as A, B, C. Then I followed these with subdivisions as illustrated below.

ELECTRIC—A

a. Motors	(a) a.c. (b) d.c.
b. Generators	(a) a.c. (b) d.c.
c. Switchboards	(a) Benchboards (b) Circuit breakers.
d. Transformers	(a) Auto (b) High tension

This method is flexible and can be made simple or very complex according to the need; or we can start with the simple form and add to it as occasion demands. In general, only the main classification and one subclassification will be needed until the envelope gets to be confusing, when it will be well to divide it.

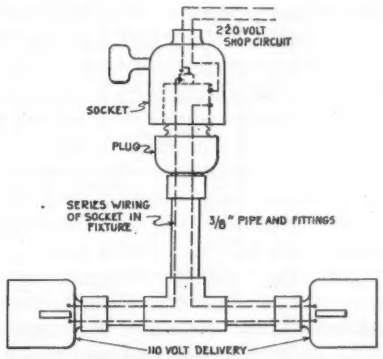
As an example of how to file an article and subsequently to find it; suppose we were interested in Features of Modern Electrical Switchgear, December 15, 1926 issue. The general head or main class is Electric, tab A; then switchboards c; then circuit breakers b. To find the article when we want it we take the envelope A from the file and turn to sheet c and inside of it to sheet b. In general we would need only two classifications.

Filing may be done in either standard letter file or other pasteboard boxes. If this is not available cheap manila paper envelopes may be employed.

Kearney, Neb. ED. SWAN.

Reduction Socket for Use on Shop Circuits

FOR A CONDITION where a voltage of 220 alone is available and lamps of this voltage are not to be had, a simple and direct means for using standard 110-v.

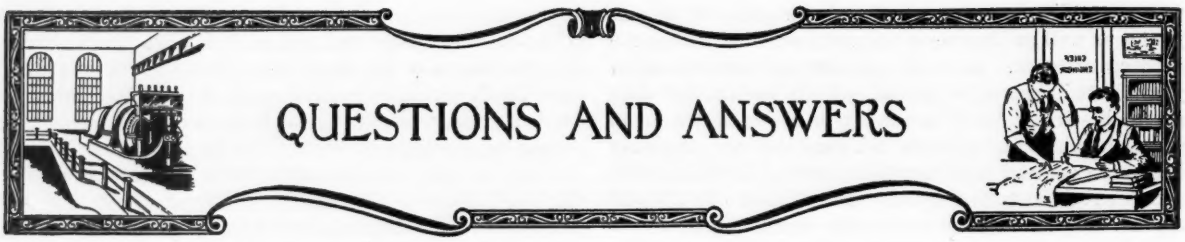


TWO 110-V. LAMPS CONNECTED IN SERIES MAKE USE OF 220-V. CIRCUIT POSSIBLE

lamps is that shown in the illustration, in which reduction sockets, wired as shown, are used. The fixture is made up of two ordinary lamp sockets, one socket plug, some short lengths of ⅜-in. pipe and couplings. The wiring of the sockets is in series. Two lamps of equal candlepower should be used in the sockets, which are wired in series; both lamps should burn at the same time.

Washington, D. C. G. A. LUERS.

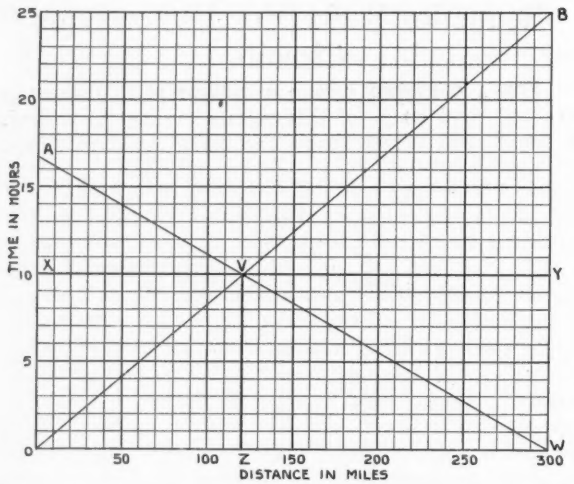
THE BUREAU OF STANDARDS, Washington, D. C., is having plans drawn by William I. Deming, 807 Seventeenth Street, N. W., architect, for a proposed new steam-operated electric power plant, for which the last Congress approved an appropriation of $200,000. The initial installation will include a 1000-kw. turbogenerator, extraction type turbine; one 300-kw. turbogenerator set, condensing; surface condensers and auxiliaries; two 500-hp. water-tube boilers, to operate at 200 lb. pressure; and the usual auxiliaries. O. T. Britt, Northwest Building, Washington, is mechanical engineer for the project. At a later date, it is proposed to increase the plant capacity to 2500-kw.



Algebraic Solution of Rate Problems

REFERRING to the question of J. E. C. on page 530 of the May 1 issue covering rates of speed to determine the point of intersection of lines A-W, B-O and X-Y at point V, the solution given was obviously obtained by cut-and-try methods.

To clarify the matter, both question and graphic solution are repeated below. The question was: "How



SHOWING RELATIVE RATES AND TIMES IN WHICH VB = B'S RATE; VW = A'S RATE; AX = 6⅔ HR.; BY = 15 HR.

can I find the rates of speed of A and B under the following conditions? A and B start at a point 300 mi. apart and, traveling toward one another, meet. After meeting, it takes A 6⅔ hr. to complete the distance just traversed by B and 15 hr. for B to complete the distance just traversed by A."

To any one conversant with simple algebraic solutions, which will lead to results which are as close an approximation to the correct values as can be obtained, the method given below may be of interest. It seems merely a coincidence that the problem under consideration leads to results with even figures while under practical conditions this is rarely the case and makes the algebraic method at least desirable for a check.

We know that distance = time × rate. Referring to the figure we also know that the elapsed time from O to V and W to V must be the same, since A and B start at the same time; we can, therefore, call this T hours. Since the distance from A's starting point to point of meeting, V, is the same as B's distance from the intersection to end of route then we can say

$$T \times R_a = 15 \times R_b \qquad (1)$$

in which R_a is A's rate and R_b is B's rate.

$$\text{also } 6\tfrac{2}{3} \times R_a = T \times R_b \qquad (2)$$

We also know that

$$6\tfrac{2}{3}R_a + 15R_b = 300 \qquad (3)$$

Equating the value of T found from (1) and (2) and solving for R_a, we get

$$R_a = \pm\sqrt{\frac{9}{4}R_b^2} = \pm\frac{3}{2}R_b \qquad (4)$$

from (3) we get

$$R_a = \frac{180 - 9R_b}{4} \qquad (5)$$

Equating (4) and (5) we find that R_b is either 60 or 12. Consideration of these two values shows that 12 must be the one to use since the distance from V to Y at the rate of 60 mi. per hr. would give 900 mi. which is, of course, absurd.

Substituting the value of 12 for R_b in (4) we find R_a to be 18 mi. per hr.

As pointed out previously the algebraic solution gives results which will be more nearly accurate when the numbers are not even.

New York City. C. O. VON DANNENBERG.

Ice Making by the Compression System

PLEASE DESCRIBE every event and operation carried out in making ice by the use of an ammonia machine.

M. W.

A. Space would not permit describing all of the combinations that are involved in the preceding question. For example, there are several methods of using ammonia as a refrigerant, two of the most common are by the compression and absorption systems. There are two principal methods of abstracting heat in the cooling process; by direct expansion and by means of brine circulation. There are two principal methods of forming the ice cake; one by the can system, the other by the plate ice system. There are two broad systems in the use of the water to be frozen; the distilled water system and the raw water system. There are many methods of harvesting ice.

We shall therefore confine ourselves to the essential elements of an ammonia compression, direct expansion, raw water, can ice system with a simple method of harvesting. Briefly, the ammonia gas is compressed mechanically in a compressor. The gas becomes heated due to the mechanical work of compression. It is, therefore, cooled in an ammonia condenser which turns it into a liquid. It then passes to a liquid receiver or tank from which it is drawn to pass through expansion cocks into the coils in the freezing tanks, finally expanding into a gas again. These coils are surrounded by a saline solution. Calcium chloride is often used for this purpose. The cans containing the water to be frozen are set in the freezing tank between the freezing

coils and surrounded by the saline solution. The purpose of the saline solution is to convey the heat from the water in the cans to the freezing coils in which, due to the expansion of the ammonia contained in them, cooling effect is produced because the work of expansion requires energy in order to produce it. This energy is absorbed by the ammonia in the shape of heat, hence the reduction in temperature by all objects in contact with the coils, including the saline solution, cans, water, etc. The solution is made saline in order to prevent it from freezing.

Raw water ice is usually made transparent in order to make it more salable, notwithstanding translucent ice is just as pure and efficient as a medium of cooling as is transparent ice. One way of doing this is to pump air into the freezing can of water. This keeps it in agitation so that in freezing, the air in the water is not entrapped. If a tube is used to convey the agitating air to the center of the bottom of the can, it may be removed after freezing by inserting a heated needle.

Impurities in the water are gradually rejected during the freezing process so that they are entrapped in the core which is the last to freeze, if it is permitted to do so. It is usual, however, to remove the core before it is frozen, by sucking it out and replacing it with clear and often distilled water.

Cranes are used for lifting the cans from the freezing tank after which they may be dipped into a thawing tank and dumped.

Crankpin and Crankshaft Sizes

PLEASE explain why the crankpin on any engine is so much smaller than the crankshaft although it has to carry the entire load. N. A. B.

A. Direct stress is not the only factor used in designing a machine member. In this case bending moments and compound stresses are involved. The greater the distance a force is applied from the support of the member, i. e., the longer the moment arm, the greater will be its bending moment, hence the greater will be the liability to bending or breaking. The force acting on a crankpin may be assumed to be concentrated at the center of the crankpin which is only a short distance from the crank cheek which is its support, while the point at which the flywheel or pulley of an engine may be concentrated is at a much greater distance from its support which is taken as the center of the bearing. Moreover, the crankshaft must resist twisting as well as bending stresses; for this reason also it must be much larger in size.

Flow of Water in Pipes

HOW MANY gallons of water will flow per minute through a 4-in. pipe attached to a city main in which the pressure is 40 lb.? C. D. S.

Flow of water through a given pipe under various pressure heads is determined by use of the following formula:

$$Q = a\,c\,\sqrt{rs}$$

where Q = quantity of water in cu. ft. per sec.
a = area of pipe cross section in sq. ft.
c = coefficient determined from experiment.
r = mean hydraulic radius = area of wet cross section divided by wet perimeter.
s = slope = pressure head divided by length of pipe, both in feet.

The internal diameter of a 4-in. pipe = 4.026 in.; the corresponding area = 12.786 sq. in. or 0.0888 sq. ft.

The pressure head corresponding to 40 lb. = 40 ÷ 0.433 = 925 ft.

Assuming the pipe to be straight and 100 ft. long, the slope will be 925 ÷ 100 = 9.25 and $\sqrt{s} = \sqrt{9.25} = 3.04$.

Assuming the pipe to be clean wrought iron pipe, the coefficient c may be taken as 93.

Kent gives the value of $\sqrt{r}$ as 0.29 for 4-in. pipe running full.

Substituting the values thus obtained in our formula we have:

$Q = 0.0888 \times 93 \times 0.29 \times 3.04 = 728$ cu. ft. per sec.

$728 \times 7.48 = 5450$ gal. per sec.

$5450 \times 60 = 327{,}000$ gal. per min. under the conditions assumed.

Steam Jets Cause Turbulence But Are Costly

PLEASE LET me know the effect of steam jets injected into the combustion chamber of a boiler furnace. I. T.

A. Steam jets function principally in causing turbulence in the combustion chamber. The steam may be dissociated, that is broken up into its elements of hydrogen and oxygen, and the hydrogen gas burned but the heat thus obtained represents a loss rather than a gain because, although the heat given off is exactly equal to that required to cause the dissociation, the heat is given off for the most part in the breeching and stack where it is of no use in heating up the water in the boiler.

Moreover, the heat necessary to raise the water thus lost in steam, from feed temperature to steam temperature, represents an additional loss. The amount of steam used in steam injection is considerable. As much as 10 per cent of the entire boiler capacity has been known to have been used in this way.

Turbulence may be more efficiently created by proper over fire supplementary air admission as described on page 245 of the Feb. 15, 1927 issue.

You would be greatly benefited by reading the various bulletins on Smoke Abatement recommended on page 1214 of the Nov. 15, 1926 issue.

Lost Motion in Duplex Pump

HOW CAN the valves of a duplex feed pump be set so that the valve gear of the one side will operate the valve of the other a little sooner so as to accomplish a more steady feed? M. W.

A. This may be done by reducing the lost motion between the nut or nuts on the valve rod and the valve. If the nut is located between two lugs of the valve, a longer nut must be substituted or washers may be placed on each side of the nut in order to reduce this lost motion. If the nuts are on each side of a central lug on the valve, the lost motion is taken up by first loosening the check nuts then moving the inner nuts equally toward the inner lug, and finally retightening the check nuts.

EDITORIAL COMMENT

The Engineer in the Business of Standardization

Standardization and simplified practice have, in the vernacular, "arrived." Originally taken up practically by engineers of the various professional societies, the benefits derived from advocated practices has been of considerable assistance and material benefit to both manufacturer and purchaser. Ultimately, of course, it is these two who would benefit from standardization, the engineer playing only an intermediate part in bringing the two to a common viewpoint and making standards that are acceptable to both.

Recently, Secretary Hoover remarked that standards are valuable only in so far as they are accepted and adopted by industry. In other words, standardization is now a business responsibility and no longer the duty of engineers who feel a moral impetus to carry on beyond their allotted tasks. This has been summed up well by Mr. McClellan speaking before the Electrical Manufacturers Association as follows:

"It is clearly understood who it is the standards have to suit and who is to accept them. The professionals know this. They know that they are in the position that the engineer always is, that of offering plans, designs, or reports for acceptance. Just as the engineer is retained to design and build a power plant which, before it is started, must be approved by the owner, so the professional engineering societies might be retained by the manufacturers and users to design and build the standards which are, however, to be finally approved or accepted by those for whom they are made and who are to be commercially benefited . . . Orderly and effective making and acceptance of standards for industry are vital parts of the serious effort America must continuously put forth to maintain her commercial eminence. From now on, competition from abroad is bound to be extremely keen . . . The American manufacturers will do well under such conditions to turn to thrift and elimination of waste in order to maintain prosperity.

"Simplified practice, resulting in only the necessary labor and material being put into a given produet and in the elimination of all unnecessary varieties must be introduced to the extreme. Standards must be established which will spur the manufacturer to offer the greatest economic value, balancing output and cost, with the minimum expenditure of labor and material. Overhead carrying costs for inventories and stocks must be reduced. All this can be the result of standardization in general and it is of basic business and financial importance to every industrial management. It is not a technical or theoretical matter to be left entirely to engineers. It is a business-producing, business-holding feature."

Certainly this acknowledgment of the business value of standardization is a tribute to the foresight of the the professional engineer whose attitude is summed up later in the statement that: "He feels a responsibility to make life easier and more effective, to reduce friction, to accomplish more with less effort, to increase equity and fair dealing and make it easier to attain them. It was this professional sense and feeling that urged professional engineers to make standards before they were apparently needed or demanded by industry."

The Easiest Way

Just as in other activities of life, in operating a power plant it is often easier to do the wrong thing than the right thing. We are thinking particularly of emergencies and abnormal conditions, rather than of routine operations in which long practice and established habit enable the operator to act correctly almost by instinct. This tendency to take the easiest way, however, although it is caused sometimes by the "cussedness" of the extremely human operators involved, in a great many cases arises from physical characteristics and arrangement of the equipment they must handle.

Modern science has been extremely successful in combating this ease of doing the wrong thing by developing automatic devices that perform operations without involving the human, fallible judgment and comparatively slow and indelicate action of a human being. If a valve or steam line bursts in the plant or something goes wrong in the "innards" of a machine, it is much harder, from a purely physical standpoint, for the operator to close the proper valves and shut down than it is to dive for the nearest exit, not to mention the question of bravery involved. When a motor-operated valve is provided in such a case, however, or some sort of remote control that can be actuated by pressure of a button, how much easier it is for someone to do the right thing! There is always danger that someone will open a disconnecting switch while its accompanying oil circuit breaker is closed, unless interlocks are provided to make the proper operation the easiest and in fact the only method. Use of automatic equipment to insure the proper performance of various apparatus is well illustrated by the power plant of the Elverson Building described in this issue.

Conversely, it sometimes happens that the design and construction of a piece of equipment makes it harder for the operator to do the right thing. In a certain hydroelectric unit, adjustments can be made to maintain the efficiency of the unit with lowering of head but, in order to make these adjustments, it is necessary to shut down the unit. It is quite probable that, since this involves some inconvenience and is not the easiest thing to do, the operators will not always make the adjustments when they should.

Every power plant engineer can think of other cases in which, when a choice is to be made between the

right and wrong method of operation, especially under abnormal conditions, the wrong one seems easier and there is danger of selecting it. Considerable attention to this point, therefore, should be given by designers and operators. Care in design and location of individual equipment, safety precautions, provision of automatic devices when justified economically, planning of operating schedules, drills and planning for emergencies —all these are of assistance in overcoming the tendency of our common human nature to take the easiest way, which is often the wrong way.

Think and Avoid Accidents

One of the best rules for avoidance of accidents is wrapped up in an important word of five letters. That word is, THINK. Whatever you are doing, THINK. Anything that is dangerous should not be done mechanically. One should always think while engaged in work involving risk.

To be a "thinker" does not necessarily insure against accident. One must be alive to what he is doing. A famous professor of engineering fell off a slowly-moving wagon not so many years ago and was run over and killed. Dr. Diesel, inventor of the Diesel engine, declared before the American Society of Mechanical Engineers that he was nearly killed at one time while operating one of his first engines. Many thinking people have been injured or killed. Most accidents, however, even among those whom we would term thinking people, are due to thoughtlessness, ignorance or foolhardiness. Of the three, thoughtlessness, inattention, is by far the principal cause.

In plants where work is liable to become humdrum and where certain operations are more or less dangerous, all machines should be safeguarded, if possible, so that accidents will not result even from thoughtlessness. It is well known that gear noises, the swishing of belts, the humming of motors and even the head-splitting riveting machines in boiler factories—all are causes of drowsiness, when continued all day long, day after day. Thoughtlessness then follows.

But, before the drowsiness stage is reached, provision should be made for safety in all operations in which those at work are liable to "forget."

Off Duty

As this issue goes to press, the world has not yet recovered from its amazement over Captain Lindbergh's daring flight from New York to Paris across the Atlantic. The news of this marvelous achievement, made singly by the 25-year old aviator with all the odds against him, has startled the entire world. For once, our customary indifference to a new scientific achievement is broken and we find everybody discussing Lindbergh. For several days even the most luscious murders were crowded off the front pages of the newspapers.

Feats of this kind make us sit up and think. What does it signify? Where are we headed for? What will the future bring? Is the success of this spectacular flight merely one nervy lad's stupendous luck or has it an absolute significance on the future of aviation? Will we some day be able to step aboard a New York-Paris air express with the same unconcern and assurance that we will arrive safely that we now board the Leviathan or will our inability to control the force of gravitation forever impose dangers too great for the common run of mankind to risk?

We have made great strides in aviation since Langley first photographed birds flying over Washington in order that he might study their manner of flight. Birds furnished us with the idea, but in the quarter of a century that we have been flying we have left birds far behind, at least, as regards speed. Ordinary bad weather is no longer an obstacle, neither is darkness. Our air mail planes fly at night with the same regularity that they do during the day. Airplane travel is a hundred times less dangerous today than it was twenty years ago.

Yet, many problems remain to be solved. In spite of all our knowledge of the principles of aviation, with all our perfected motors and improved materials, air travel cannot be said to be safe. Gravity is always with us and even the best of motors may stop. Forced landings are dangerous.

What about speed? Lindbergh made good time—just about a hundred miles an hour. Is this fast? Compared to the speed of a transatlantic steamship it is. Compared to a bird's flight it is. Yet, compared to the speed of certain insects it is slow.

There is a little fly, the muscoid bot of the cephonemyia family, whose speed of flight puts even the fastest airplane to shame. One of these insects, starting from New York for Paris at the same instant that Lindbergh started, would have reached Le Bourget about 30 hours before the airplane, for this insect flies at the incredible speed of 815 miles per hour—three times faster than the fastest airplane.

This gives future aviators something to aim at. If we can discover how this astounding fly attains this bullet-like speed, we shall no doubt have new principles for developing future aviation. In determining the secret of the muscoid bot's speed, the high speed motion picture camera can be of great help. The solution of the speed problem is of tremendous importance in aviation, since with a high enough speed, the effect of weather conditions can be made negligible. Storm areas are rarely of such extent that with a speed of 800 miles an hour, they could not be avoided.

We have heard of fairies dancing on a ray of light. In a recent issue of Tycos-Rochester, Dr. Hubbard of the Bureau of Standards, says we can do almost that now, with a new radio beacon devised by the bureau. The flier rides on a slender ray of directed radio, like a searchlight beam, which guides the airplane to its proper destination. As long as the flier keeps on the beam, he hears the letter T repeated intermittently. Should he deviate to the right or left, however, he hears the signal "N" or "A" as the case may be. In a late development a white light flashes when he is on the beam and a red or green when off.

With such an arrangement an airplane could easily be steered automatically. The automatic power helmsman has already arrived, thanks to the gyrostat. It is easy to imagine future air travel guided by such slender, invisible beams of radio, along lanes which automatically steer the planes and help them on their course to their destination.

Who can say that any of these things are impossible? Judging by the events of the past 25 yr., what we can do is limited only by the fertility of our imaginations.

High Pressures and Industrial Power Among Leading Topics at A. S. M. E. Meeting

NESTLED in the mountains of West Virginia, with all facilities for technical concentration and sports relaxation, White Sulphur Springs was the ideal setting for a week of mental and bodily development of engineers in a series of meetings which contributed important and interesting knowledge on large central station experience, hydraulic turbine and plant design and the economics of industrial power plants. Half of each day was devoted strictly to technical meetings and discussion, the balance to sports, social relaxation and better acquaintance. The result was voted a success by all who were fortunate enough to attend.

Simultaneous sessions were held each morning on different branches of engineering but only those dealing with power plant matters will be included. At the same time meetings were held by the A. S. M. E. and the A. S. R. E., the two societies joining in social activities. Papers of both societies, which are of interest to power engineers, will be summarized or abstracted.

Central Station Power

In this division, three important papers were presented Monday afternoon. Messrs. I. E. Moultrop and E. W. Norris gave the results of experience with a 1200-lb. pressure installation at the Edgar Station of the Edison Illuminating Co. of Boston; Alex D. Bailey told of experience with high pressure and temperature steam at the Crawford Ave. Station of the Commonwealth Edison Co. of Chicago; Everett O. Waters and J. Hall Taylor outlined an analysis of strength and stiffness of pipe flanges and a method for designing flat ring and hubbed flanges to meet given conditions.

1200 Lb. at Edgar Station

Experiments and analyses leading up to the design of this station were outlined resulting in the adoption of 1200-lb. and 700-deg. steam expanded in a 3000-kw. turbine to 375 lb. and 500 deg., then reheated to 700 deg. and delivered to the 350-lb. header for expansion through "normal pressure" turbines down to 1 in. absolute. The power in this latter expansion is 12,000 kw., giving 15,000 kw. from the 1200-lb. boiler.

Weekly performance data show an average of 1.02 lb. coal per kilowatt-hour without high pressure and, with 1/3 the station steam generated at high pressure, this dropped to 0.98 lb. per kw-hr., a gain of 4 per cent. With full operation at high pressure, the gain is estimated at 12 per cent.

Details of equipment were given as can be found in Jan. 1, 1927, issue of Power Plant Engineering.

Some tendency has been found for slag accumulation on the lower boiler tubes at heavy loads. Initial difficulty with gaskets on hand-hole covers was overcome by changing the gasket material. Hand regulation of water level was found troublesome but was remedied by installing a feed water level regulator. In normal operation, foaming is not encountered even with sudden increases of load but, with water level nearly at the top of the glass, some moisture is carried over. Safety valves are found reliable and pilot safety valves, set to blow and give warning below popping pressure, have been removed.

No superheater or reheater trouble has been encountered and no economizer trouble except with gaskets for tube hole covers, which disappeared when compressed asbestos was used.

Stoker firing is used, the furnace running somewhat hotter than normal because of reduction of radiant-heat-absorbing surface from use of 15-ft. tubes instead of 20-ft. Slight trouble with the front arch was overcome by ventilating the arch.

For the 20-stage, impulse turbine, carbon block shaft packing failed because of vibration but the labyrinth rings substituted have been satisfactory. After 1800 hr. service, a light deposit of iron rust was found on the interior and buckets showed traces of pitting as did exterior piping, assumed to be due to incomplete deaeration of feed water. Provision of a secondary squirrel cage winding to permit putting the generator on line when considerably out of step was found unnecessary and the laminated field required for this winding produced vibration when running above critical speed. As the provision was not needed, the secondary winding was removed and a solid field substituted, which has cured vibration.

Auxiliary equipment such as multiple stage feed pumps, bypass valve for high-pressure steam to the normal-pressure header, valves, piping and fittings, which are of normal design but with thicker metal, have given no difficulty. Castings for valve parts and fittings were X-rayed to detect hidden defects, resulting in about 25 per cent rejection but no leaks have developed in castings accepted after this test.

After 2-yr. operation no difficulty appears in handling the 1200-lb. installation and that part of the plant has been found especially convenient to operate.

In extending the Edgar Station it is considered desirable, because of economies and space available, to change from 30,000-kw. to 60,000-kw. units. Comparison of costs and results was made for extending the 350-lb. section, for extending partly the 350-lb. and partly the 1200-lb. sections and for making all the station 1200 lb. Increase from 350 to 1200 lb. would increase output nearly 30 per cent for the same building space, with marked fuel saving, so the first extension is to be for high-pressure steam, a 10,000-kw. high-pressure turbine, a 65,000-kw. normal-pressure main unit and two high-pressure boilers. The main generator is 60,000 kw. with a 5000-kw. auxiliary-power generator at the end of the shaft. The complete unit will have four boilers and two 10,000-kw. high-pressure turbines exhausting to the 65,000-kw. main unit, giving gross output of 85,000 kw. at 80 per cent power factor.

By using headers for the boilers, the high-pressure turbine exhaust and the 350-lb. steam, any of the high-pressure boilers and turbines can be operated with any of the normal pressure turbines, thus securing maximum flexibility.

Water flows from hot well pumps through air and oil coolers of the main unit to the low-pressure extraction heater, the evaporator condenser and the deaerator, which is also an intermediate extraction heater, with a cool surge tank floating on the line between primary heater and evaporator condenser. Normal boiler feed supply is from motor-driven pumps, arranged in two pressure groups, drawing from the deaerator and discharging into a feed heater at 400 to 500 lb., which parallels the supply to the main boiler plant. From this header, secondary pumps deliver to a 1400 to 1500-lb. header through two extraction heaters. The first is the high point heater from the main turbine; the second takes supply from exhaust of the high-pressure turbines. This steam generates about 2500 kw. in the high-pressure turbines at 100 per cent thermal efficiency, since the exhaust heat is returned directly to the boiler in the feed water. For emergencies, a steam-driven pump delivers directly from deaerator to the high-pressure feed system.

High-pressure boilers are cross-drum type with lower bank tubes 3¼ in. diam. by 19 ft. long set 8 in. centers in vertical headers. Above this bank is the primary superheater of convection type and the upper bank of 2-in. tubes 18 ft. long in three passes with inclined headers. Above these is the reheater, two superheaters, set transversely, with drums in the side walls and piped in parallel. Large surface is used to give the needed reheat with the comparatively cool gases between the first and second pass.

Main turbines are 17-stage, single flow with four extraction points. High-pressure turbines have 16 impulse stages, with casing made of two solid forgings.

Main turbines are governed in the usual way, high-pressure turbines either by speed of the unit or by pressure in the 350-lb. header, the speed governor being used until the unit is on the line at speed, the pressure governor then operating to maintain constant pressure in the header.

As to possibilities above 1000 lb. pressure, it was pointed out that by using independent high-pressure turbines at high speed, the same efficiency can be maintained at all initial pressures as with the single casing turbine at moderate pressures. Using air heaters and economizers with surfaces properly proportioned to boiler heating surface, any desired exit gas temperature can be maintained. Power required by auxiliaries increases, however, at high pressures and becomes a serious consideration in limiting the advantages of very high pressures.

As to equipment, mechanical strength and characteristics of materials are the problems. Commercial steels are satisfactory up to 700 deg.; above that alloy steels with high per cent chromium come into use. Present practice is limited at 750 deg. but trials up to 900 or 1000 deg. are under discussion and researches on materials at high temperatures may bring a solution. Intermediate reheating either with furnace gases or high-pressure steam gives dry steam in the last stages, the same as the higher initial superheat, the choice depending on relative cost of the two methods.

Turbines, valves and piping for extreme pressures seem to offer no impossible problems but casings, shaft packings and details of feed pump require careful design.

Studying the percentage of heat in steam available for useful work, or Rankine efficiency, the increase is rapid at low pressures, but slower as pressure increases. Between 600 and 1200 lb., the gain is 6 per cent; 1200 to 1800 lb., 2 per cent; 1800 to 2400 lb., 0.3 per cent. These figures are for constant maximum temperature of 700 deg. and higher initial temperatures will move up the gain with pressure. Determination of highest profitable pressure will depend on cost of fuel, capital cost and load factor but, for all cases, a limit is set by decrease of rate of thermal gain and steady increase of auxiliary power losses as pressure is increased.

Because of the small space requirement for high-pressure turbines, the complete high-pressure unit takes less space per kilowatt capacity than the normal-pressure unit, so that gain in thermal efficiency is nearly net economic gain, which may offset increase in first cost due to the high-pressure construction. The conclusion is, however, that there is little inducement to increase pressures above 1200 lb. except as cost of fuel rises and investment cost may be reduced by experience in building and operating high-pressure plants.

In discussion it was stated by John Anderson that adding radiant heat surface will help furnace troubles by lowering temperatures, that at 1400 lb. no piping trouble has been found, that Stirling boilers have some advantages for high-pressure work, that stokers are not suitable for highest temperature air preheating, that extra cost of a 1400-lb. plant would be repaid by one year's savings and that, after 2500 hr. running, at 1200 lb., a 7500-kw. unit was found to be in as good condition as at the start.

Pressure and Temperature Limits

In the second paper, presented by Alex D. Bailey, experience with high pressure and temperature steam was given at length and an extended abstract will be given later.

Discussion brought out advocacy of the use of higher pressures and temperatures in the larger industrial plants, Dr. W. N. Polakov citing an instance in a large paper mill which uses 500,000 to 600,000 lb. of steam an

hour and purchased 40,000,000 kw-hr. a year. Superposing a high-pressure plant delivering 750 deg. steam and exhausting to the older plant gave 20,000 lb. of steam extra and effected a fuel economy of $160,000 a year. Desuperheating was used when needed for process steam.

F. Hodgkinson stated that increase of pressure was better, thermodynamically, than increase of temperature at a fixed pressure and that there would be no trouble in building turbines for higher pressure but might be for very much higher temperatures than 750 deg. The difficulty is not with details but the expansion and strength effects on large structures such as turbine casings.

Professor A. G. Christie, however, felt that temperatures up to 850 deg. should be adopted, which would avoid the need of reheating after partial expansion.

Question was raised by Mr. Loughnan Pendred of London, England, as to the most economical pressure and temperature considered from a cost of unit steam or power. He commented on the higher investment per unit capacity here than in England and the research in England as to the effect of prolonged high temperature on the strength of steel.

George A. Orrok said that study of a large number of plants showed costs ranging from $49 to $256 per kw., the average being about $100, and fuel efficiency in the boiler plant of 70 to 80 per cent. He felt that 750 to 800 lb. is likely to be found the best pressure and 850 or possibly 900 deg. but these points will be reached only after considerable more experience. A 2500-kw. turbine which he saw in Europe ran at 850 deg. and the casing was red hot, but it had run 2 yr. with the only trouble from superheater tubes and a 5000-kw. unit has been ordered for the same conditions.

W. S. Monroe sent a description of a Benson boiler, built by the Siemens-Schuckert Co. which runs at 3200 lb. and 840 deg., the steam being throttled to 2560 lb. at the turbine and reheated to 840 deg. after partial expansion.

Commenting on high furnace temperatures, H. W. Leitch stated that, with powdered fuel, water-cooled walls become coated with a slight glaze which reduces cooling effect until a balance is reached between absorption and reflection of heat, thus lessening any tendency to overcooling.

Water walls have been found essential when using preheated air for both pulverized fuel and stoker-fired furnaces. Mr. Bailey said that his plants have used up to 275 deg. for heated air and, by cooling the chains of the chain-grate stokers, they expect to go to 350 or 400 deg.

New boilers at the Edgar Station will have water-cooled walls on back and sides, Mr. Norris said and will be stoker fired.

Pipe Flanges

Considerable difference of opinion was expressed in the discussion on pipe flanges as to what strains should be provided for. It was pointed out that brutal erection may change conditions of application of stress, also that stiffness against deflection was of as great importance as strength in preventing leaks.

The formulas of the paper by Professor Waters and Mr. Taylor, resulting from a logical analysis of stresses in flanges, have been reduced to graphical charts for plain and for hub flanges, which can be had from Mr. J. Hall Taylor by writing to the American Spiral Pipe Works, Chicago, Ill.

While trouble has been experienced with steel cast fittings and several engineers were inclined to avoid their use, it was shown by Mr. Norris that where tests by X-ray were made for defects, resulting in rejecting about 25 per cent of fittings, no trouble was found after erection.

Low Temperature Carbonization

In a paper on the Economics of Coal Carbonization in the United States, Mr. George A. Orrok reviewed the history of coal carbonization, as developed through the beehive oven, and the progress to by-product ovens. Coking commenced in the United States in 1841 with the beehive process and grew rapidly until there were 100,000 ovens working in 1910. From that time there was a decrease in the popularity of this process because of the increasing use of by-product ovens, which began in 1893.

By 1926 there were 55,000 beehive ovens and 11,300 by-product ovens, the product of the respective processes being 11,500,000 tons and 44,500,000 tons of coke.

Chief among the by-products is ammonium sulphate which, in 1926, yielded 38 per cent of the inorganic nitrogen supply of the United States, 56 per cent being furnished by imports of Chilean saltpeter and 4 per cent by air fixation. In the use of this nitrogen, 36 per cent is accounted for by fertilizers which, it will be noted, is about the same amount as that produced by the by-product ovens; 28 per cent was used in the refrigeration industry, 12 per cent in explosive and chemical industries and 24 per cent was exported.

The value of the ammonium sulphate produced depends on the market value of Chilean saltpeter and, if the price of saltpeter should fall on the conclusion of the producers' agreement, it would affect seriously the market for ammonium sulphate.

Other by-products are benzol, a competitor of gasoline, and light oils which may be used for lubricating and fuel purposes.

It is found that, in order to produce the best coke for metallurgical purposes, high temperature carbonization is necessary, hence the by-product ovens, which at the present time are largely operated in connection with steel works, are run on the high temperature principle, mostly from 1600 to 2100 deg. F.

Low temperature carbonization gives a fuel better suited for domestic use and yields larger volumes of tar but less gas and ammonium sulphate. Plants with capacities up to 200 tons a day are in operation in England and Germany, the resulting coke being largely marketed for domestic use and for power plant fuel. The low temperature range is from 660 to 1300 deg. F. It would seem that for any large production of low temperature coke, the power plant must be the market, as this coke has proved too fragile for blast furnace use. Utilization of the other by-products, gas, tar and ammonium sulphate, is problematic, the only assured market being that for the light oils.

In an investigation made by Dr. G. Klingenberg, the conclusions were reached that, when coal costs more than $1.50 a ton and the income from by-products

amounts to less than $1.62 a ton, direct firing of coal for power purposes is superior to gasification; that, as long as coal is under $3.50 a ton, by-product plants work more economically in connection with steam turbines than with gas engines; that gas engine plants are to be considered only when coal costs more than $3.50 a ton and the income from by-products amounts to at least $2.50 a ton of coal; that direct firing of coal for all load conditions and for reasonable coal prices is the cheapest method of operation so long as income from by-products is less than $2.00 per ton of coal processed.

Dr. Klingenberg points out that, although certain valuable ingredients are destroyed when firing the raw coal, yet a less tonnage of coal is required for power plant fuel when the coal is fired direct than when coke is used, so that carbonization of power plant fuel is not a method of coal conservation. He also pointed out that the carbonizing plant must run at 100 per cent load factor or expense will be prohibitive, while the power and lighting loads seldom have as high as 50 per cent load factor. Even plants which are built as base-load plants find that the load factor on turbines five years or more old has dropped to 32 per cent, because of the building of more efficient generating units.

While this investigation was made in 1917, improvement in economy of power generation has been such that the processed fuel is even less attractive than at that time and it would seem that, until coal prices are much higher than at present and the market for by-products is made certain, direct firing of coal will give a better combination of fixed charges, overhead and operating cost, with simpler plants and fewer chances of interruption, and that this will determine the economic advantage to the public.

Colonel H. D. Savage pointed out the difference in requirements for metallurgical, power plant and domestic fuel and that a different process is needed for each. For metallurgy, a high-temperature coke. For power use, a powdered fuel such as that given by the Runge system. For domestic fuel a sized fuel, as produced by the K. S. G. or Essen method.

Considerable discussion, when analyzed, brought out the points that demand for a better domestic fuel than raw bituminous coal makes it likely that low temperature carbonization may be successful commercially even though the processed fuel sells at a higher price than coal. The best field is where prices on by-products such as gasoline and oils are high. Uncertainty as to the market for by-products and the small margin of profit make the economy of processing for power fuel problematical. It is likely to come but not in the immediate future.

Discussion in the hydraulic session was largely of a nature comprehensible only by specialists in turbine and penstock design. The paper by Mr. Lee giving details of rack and headgate design is abstracted at length.

Consensus of opinion on the proposed characteristic formula by Arnold Pfau was that the head, speed and power should be found in such a formula and that the one now in use was familiar, contained these quantities and was reasonably satisfactory, although the one proposed might be based on more exact analysis.

It was shown in a paper on water hammer by Ray S. Quick that the elastic water column theory gives an accurate means for investigating rise of pressure in a closed pipe line and charts were given for determining such rise for uniform gate motion and for complete closure. Pressure travels by wave action and it was shown that calculated and tested pressures agreed closely. For each penstock there is a natural form of wave of pressure change with time and, if gate closure is to occur during a few wave periods, damping of waves of pressure is of little consequence. Friction is an almost negligible factor. Maximum pressure will occur, in most cases of high-head plants, at the end of the first pressure-wave internal, hence slowing down gate motion near closure may be of little assistance in such cases. For low-head plants such a slowing down may reduce maximum rise of pressure.

Oil and Gas Power

This session was concerned with developments of the high-speed oil engine of Diesel type, looking toward the adaptation of that type for airplanes and automobiles. The study of oil sprays by moving pictures is outlined elsewhere. Carlton Kemper gave the requirement for the fuel injection engine as reduction of weight from 25 lb. per horsepower to 3 lb., which means increasing the speed from the present 300 to 600 r.p.m. range up to 1800 r.p.m. Difficulties to be overcome are spray distribution and atomization, turbulence, time for vaporization and ignition. He showed that for 1800 r.p.m. the fuel injection interval is 0.003 sec., while for present slow speed engines the time lag of ignition is 0.02 sec. This time lag must be shortened or explosive effects will result after the entire change is in the cylinder.

High explosion pressures of the Otto cycle and burning after cutoff with the Diesel cycle have led to use of a dual cycle in which a small portion of the fuel burns at constant volume, the remainder at constant pressure. For this cycle at high speed, fuel must be so prepared that ignition is almost instantaneous and the combustion chamber must cause turbulence and mixture of the air and fuel which will result in complete combustion.

Partial burning in a pre-combustion chamber and metering through a neck or orifice to give constant pressure combustion in the cylinder, which has been used, reduces the mechanical efficiency of the engine at high speeds because of friction through the orifice, lag of gas pressure on the piston and greater loss to jacket water. It gives better turbulence and combustion, hence lower fuel consumption.

Combustion Chambers

Most important requirements for high-speed engines are complete distribution of spray and turbulence to insure complete burning throughout the combustion chamber. Tests have been made on single-cylinder engines, 5 by 7 in., driving 50 to 75-hp. dynamometers. For a standard Liberty cylinder and special piston, explosion pressures up to 1600 lb. were found which resulted in mechanical difficulties but showed that fuel-injection engines could be run at high speeds.

Special forms of cylinder head were then tried, having a flat, fan-shaped spray, both with and without flow of inlet air directed to remove products of combustion from around the fuel valve. Directed flow increased mean effective pressure and reduced fuel consumption by 14 to 17 per cent.

Another type of head, with bulb type of pre-combustion chamber, showed practically complete combustion for loads up to the point where air supply was insufficient but indicated low mechanical efficiency. When a tangential air jet was fitted to give high turbulence in the bulb during compression and in the cylinder during expansion, operation was smooth and regular at all loads. Rounding orifice edges and flaring to discharge burning gases over half the piston area increased power output 8 per cent.

Results seem to indicate that the problem is to be solved by complete mixing of well atomized fuel with air charge, which may be accomplished by design of the combustion chamber, and by reduction of time lag of ignition, which can only be by better preparation of the fuel charge before ignition, possibly by pre-heating.

High-Speed Indicators

For investigating high-speed engine action, the low-speed indicator has been adapted by Professor H. M. Jacklin so as to give a progressive point-by-point diagram, averaging the results of 800 cycles for a 4-stroke cycle engine and 400 cycles for a 2-stroke cycle. By offsetting the time of operating the driving mechanism, action during compression, ignition and combustion can be spread out so as to be more readily studied. Adaptation can be made for taking diagrams simultaneously from all cylinders of a multi-cylinder engine, using an indicator for each cylinder. Load conditions must, of course, be kept constant, as the diagram is an average of all cycles during the process of taking the card.

This method has been used successfully on engines and air compressors for speeds of 600 up to 2960 r.p.m.

Discussion was largely on difficulties in high-speed work with various forms of indicating apparatus and questions as to details of the experiments with oil sprays and combustion chambers.

Industrial Power

Speaking from the engineer's viewpoint on management of industrial power plants, Henry F. Scott was of the opinion that the power plant should be considered as a separate or subsidiary concern for supplying power, light and heat to other departments and the same executive ability should be required from its head as from those of other departments. Investment in power equipment or additions should be considered by comparing probable cost of operation with past performance and with estimated cost of purchasing power. This necessitates a complete power accounting system showing costs for material and labor of generating distributing power plant product, also the quantities supplied to each department.

Responsibility for this work should rest in an experienced engineer, capable of advising the management and of deciding when to call upon specialists for counsel.

Responsibility of the power plant engineer includes continuity of service, economy in production, compliance with state laws and regulations and with safe standards both as to employes and equipment.

Maintenance and plans for repairs are greatly facilitated by careful inspections, regularly made. To control operation, combustion, draft, temperature, feed water and load distribution, suitable instruments are essential. Equipment, even though not the best for the purpose, should be operated so as to give the best economy possible and requirements as to power and heat balanced so far as may be by control of auxiliary equipment and manufacturing processes. Waste of exhaust steam or hot water is a source of loss usually possible to correct.

As capacity of a plant is approached, the engineer should give sufficient warning so that additional equipment may be ready when needed.

Continuous tests and records of working performance should be compared with possible performance of equipment and study of graphic charts will often show losses due to inefficient use of steam in factory processes. Load factor of 100 per cent on equipment in operation is the best condition for economy and should be sought, though it is rarely possible except for short periods.

As a rule, design of power plant should be left to specialists but the management should influence decision as to the amount of power to provide and the plant engineer should have approval of equipment to be used.

F. M. Gibson emphasized the need of adequate records and that industrial plants should take advantage of improvements developed in central station practice. He instanced one case where introduction of instruments and records saved 30 per cent in the cost of steam used.

In charging power to departments, an equitable method is to apportion heat and light according to floor space and power according to current used. Process steam should be metered or charged according to pressure, size of main and time of use.

From an executive's viewpoint, Walter N. Polakov said that he should know what his plant can do, whether it is doing it and, if not, why not. He gave a logical presentation of how this information may be obtained, illustrated by lantern slides of inspection schedules, job tickets for repair, cost keeping methods, plans for budgeting and comparing actual costs by months. He advocated the use of plenty of meters for steam and current so that costs may be properly allocated to departments, the use of exhaust steam in place of live steam where possible, staggering of peaks on power and process work and provision of proper equipment to give easiest methods for the workers. Finally, standards of performance should be set, comparison made of accomplishment with these standards and reward given for meeting or exceeding the standards. These should be so planned that comparison can be made for each shift, each day and total by weeks or months.

In the discussion, participated in by a considerable number, the chief points brought out were that, although the cost of power is often but a small part of the total cost of product, many plants do not know what their power is costing and large wastes occur which have an important bearing on profits. Good professional advice and cost systems are needed to reduce losses, but continuity of operation is usually more important than fuel economy.

Mr. Polakov stated that coal, on the grate, may cost 1/4 to 1/3 cent a pound and that several pounds of coal are often used per pound of product. A reduction of 10 to 20 per cent in fuel used may appreciably affect the cost of product and help to meet competition.

W. L. Badger's discussion of evaporators dealt largely with those used for large industrial process work,

many times the size of the ones needed for power plant make-up water. Rate of transfer of heat increases with steam temperature and with temperature difference between steam and water and is largely affected by the thickness of the condensate film which offers the main resistance to heat transfer. Viscosity of water varies 500 per cent between 32 deg. and 212 deg. and the hotter water circulates more rapidly, hence forms a thinner film.

Rust also is bad. An evaporator with a year's rust accumulation showed a heat transfer rate of 200 and when cleaned rose to 600. Copper showed 2000 and when cleaned and polished rose to 4000.

Multiple effect evaporators should be fitted to the conditions of service. The rate can be varied from 1.9 to over 4 lb. of water per pound of steam. The multiple effect increases economy but has less capacity for a given total surface than the single effect. There is no such thing as "efficiency" of an evaporator and its performance cannot be judged on any such basis.

Speaking of power plant evaporators, Mr. Robinson said that they are mostly single effect, of small capacity, planned to operate partially scaled and with scale removed by deformation of tubes.

World's Largest Hotel Makes Own Power

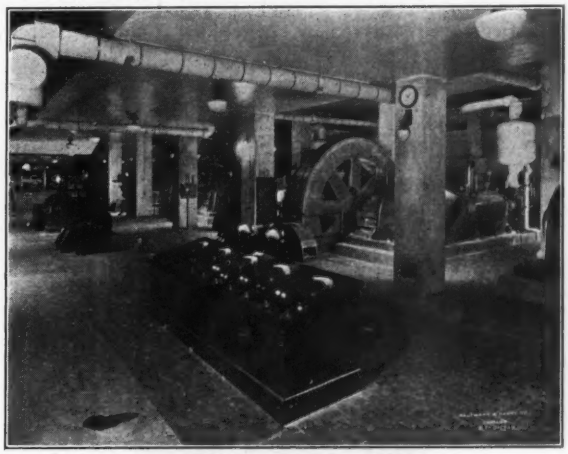
ELECTRICITY for light and power in the new Stevens Hotel in Chicago will be supplied by three 750-kw. cross-compound, one 500-kw. single and one 350-kw. single Hamilton Corliss engines driving direct-connected Westinghouse 230-v. d.c. generators.

Steam will be supplied at 175 lb. by three 597 and four 686-hp. Heine V Type boilers fired by McClave-Brooks Co. chain grate stokers designed for 200 per cent boiler rating and with an area of 133 and 154 sq. ft. respectively. The boiler will be equipped with Ashton safety valves and Diamond soot blowers, Golden-Anderson stop and check valves, Republic meters, Homestead blowoff valves and A-Jacks damper regulators. Piping for both high and low pressure was supplied by the National Tube Co. and is used with Crane Co. fittings.

Two Worthington duplex pot valve and one Ingersoll-Rand multi-stage centrifugal boiler feed pumps are provided and used in connection with two 100,000 lb. per hr. Cochrane open metering type feed water heaters designed for 5 lb. back pressure.

Coal will be received by car through the Illinois tunnel or by truck and distributed to the bunkers by a Jeffrey pivoted bucket conveyor while ashes will be elevated by a Jeffrey elevator or by an 8-in. United Conveyor Corp. steam jet conveyor. Sewage will be handled by Shone duplex ejectors and a Yeomans Bros. Co. steam turbine driven centrifugal ejector will be provided for standby service. House pumps consist of two Murray high-duty cross-compound pumping engines and two Worthington motor-driven centrifugal pumps.

Fourteen passenger elevators, ten service elevators, two hydraulic lifts, two dumb waiters and one 10-t. freight hoist are provided. The elevator electrical equipment was especially designed by the Westinghouse Co. Two 125-t. Carbondale exhaust steam absorption refrigerating machines and two 125-t. Worthington compressors will be used for refrigeration, ice making and air conditioning. Over 130,000 sq. ft. of American Radiator Co. radiators will be used and all public rooms will have National Regulator Co. temperature regulators. Warren-Webster vacuum traps will be used on all radiators and the ventilating system fans will be the Clarage new type HV, driven by motors.



ELECTRIC POWER IS GENERATED WITH CORLISS ENGINES AT THE NEW STEVENS HOTEL IN CHICAGO

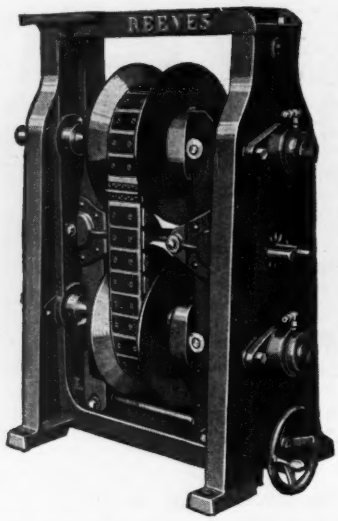
This is the largest hotel in the world, containing some 3000 rooms and was formally opened on May 2. Holabird & Roche were the architects. Geo. A. Fuller Co. was the general contractor and W. A. Bird is the chief engineer of the hotel.

A. S. M. E. Announces 1928 Nominations

NOMINATIONS FOR OFFICERS of The American Society of Mechanical Engineers for 1928 were announced at a recent meeting of the Nominating Committee held at White Sulphur Springs, W. Va. Election will be by letter ballot of the entire membership, closing on September 27, 1927. The nominees, as presented by the Regular Nominating Committee of the society, are: For president—Alexander Dow, president, Detroit Edison Co., Detroit, Mich.; vice-presidents—John H. Lawrence, vice president and engrg. manager, Thomas E. Murray, Inc., New York, N. Y.; Newell Sanders, Newell Sanders Plow Co., Chattanooga, Tenn.; Edward A. Muller, vice president and general manager, King Machine Tool Co., Cincinnati, O.; Paul Wright, Paul Wright & Co., Birmingham, Ala.; managers—William A. Hanley, chief engineer, Eli Lilly & Co., Indianapolis, Ind.; Luther B. McMillan, chief engineer, Johns-Manville, Inc., New York, N. Y.; Fred H. Dorner, Milwaukee, Wis. Delegates to American Engineering Council—Alex Dow, Detroit; D. S. Kimball, Ithaca; R. C. Marshall, Washington; L. P. Alford, New York; H. V. Coes, Chicago; Wm. S. Lee, Charlotte; A. M. Greene, Jr., Princeton; David W. Brunton, Denver; and John L. Harrington, Kansas City.

New Vertical Speed Transmission Requires Little Space

FEATURING the small floor space required for installation, a new vertical design of Reeves transmission has been developed by the Reeves Pulley Co., Columbus, Ind. It carries the standard internal parts of the Reeves and follows the same operating principle. Speed variation is accomplished with two sets of cone faced disks connected by a V-shaped belt fitting into the V-shaped throat formed by the disks. A shifting screw,



THIS VERTICAL VARIABLE SPEED TRANSMISSION WAS DEVELOPED FOR INSTALLATIONS WITH LIMITED SPACE

which operates in either direction, shifts two levers which are connected on each side of the disks. These levers separate one set of disks and simultaneously bring together the other set, so that as the diameter of one pulley increases, the diameter of the other decreases. In this manner any speed variation between the fastest and slowest is obtainable with a steady, positive flow of power.

Hot Water Heating Effects with Steam

FOR USE with vacuum or atmospheric return line systems of steam heating, Johns-Manville Corp. has perfected the Johns-Manville radiator control valve to give regulation of radiator temperatures comparable with that of hot water heating. The valve is built of brass and bronze, rough nickel plated body and polished nickeled trimmings.

Operation of the valve will be understood from the accompanying sectional cut. Below disc A is a sleeve C with slot D, which is gradually exposed as the disc rises, allowing steam to flow through nozzle E and venturi tube F. This flow creates a partial vacuum at G, drawing the heating medium from the radiator back through passage H to G, mixing this medium with the incoming steam and carrying it back to the radiator. This mixture has a temperature lower than that of the steam supplied depending on the quantity of steam admitted through nozzle E.

For quick heating, in the morning or extremely cold weather, the valve is opened wide, raising disc A and sleeve C clear of the seat and allowing steam to flow through tube F and passage H so as to fill the radiator

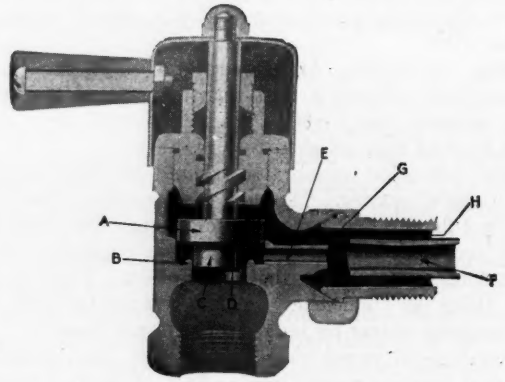


FIG. 1. SLEEVE AND SLOT ACTION PERMIT CONTROL OF STEAM RADIATOR TEMPERATURE

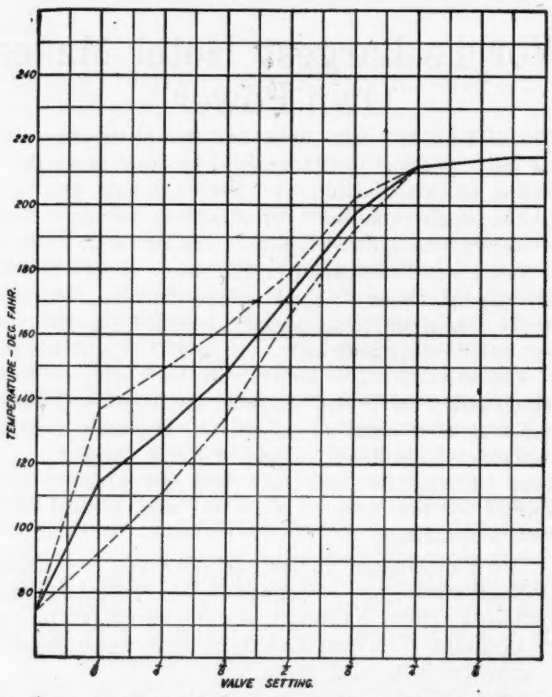


FIG. 2. VARIATION OF RADIATOR TEMPERATURE WITH SETTING OF JOHNS-MANVILLE RADIATOR CONTROL VALVE

with live steam. When operating with the mixing action, the hot mixture will be driven to the farther sections of the radiator and the return to the mixing chamber will be through the connecting nipples and the first section. The valve may be connected to the top of the first section as in hot water type radiators now generally used in steam heating or at the bottom, if steam pattern radiators are used.

Advantages of hot-water heating are recognized in giving any desired radiator temperatures for mild weather, which gives more even distribution and circula-

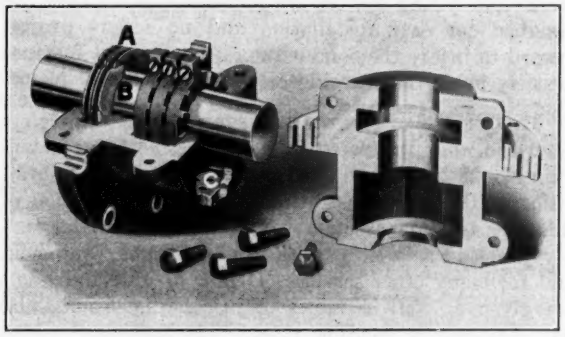
tion of heated air, resulting in more even room temperature and more healthful conditions. There is also less heat loss from the sides, windows and ceiling of the room with resulting economy. Convenience of quick opening and closing is secured as the valve goes from tight closed to full open in 7/8 of a turn of the handle.

Figure 2 shows the radiator temperatures obtained at various openings of the valve on a 15-column radiator of hot water type, 26 in. high and with 40 sq. ft. heating surface, using steam at 1 lb. gage pressure. Return was at atmospheric pressure through a radiator trap. Dotted lines show average temperatures at tops and bottoms of columns and the full line average temperature for the entire radiator. But few degrees difference was found between temperatures of sections farthest from the valve and those nearer to it.

Three sizes of valve are made, for ½-in., for ¾-in. and for 1-in. inlet. The first is for radiators up to 20 sq. ft. surface, the second for 20 to 60 sq. ft., the third for over 60 sq. ft. All have ¾-in. spud connection.

Oil-Return Wall Plate Metal Packing for Compressors

GARLOCK PACKING CO., Palmyra, New York, has just placed on the market a new type of metal packing, which is known by the above trade name. It is designed to replace oil wiper packing in the wall plate



PRESSURE-VACUUM RING AND SPECIAL WIPER RINGS FOR COMPRESSOR PISTON ROD

stuffing-boxes of gas and air compressors, so as to reduce consumption of lubricating oil, and oil in the compressed air or gas as delivered.

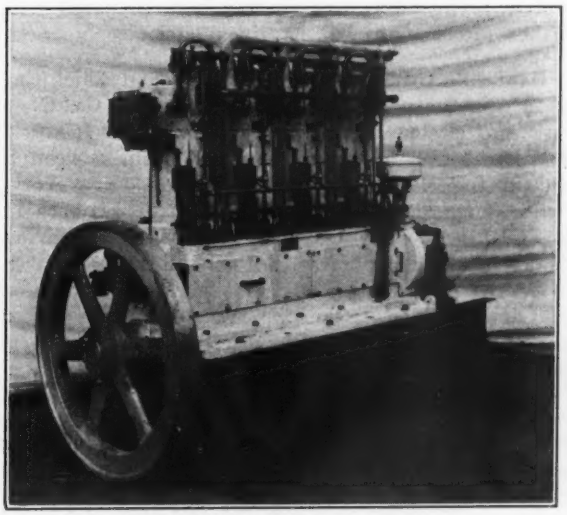
This device is stated to wipe oil from the compressor piston rod and return it freely to the crank case. It is furnished in either split or solid case which is bolted to partition wall plate after the stuffing-box is removed.

Pressure-vacuum ring A faces the cylinder side of the wall plate, while oil wiper rings are shown at B. At C are holes in the bottom half of the split case through which the oil returns to the crank case.

Diesel Cylinder Size Increased

CONSERVATIVE power rating and a considerable overload factor are featured in the new Wolverine Diesel by the Wolverine Motor Works, Bridgeport, Conn. For instance, the 95-hp., 350-r.p.m., four-cylinder engine has been increased from 8¼ by 11 in. to 8½ by 12½ in. in order to secure this overload capacity and take care of continuous 24-hr. operation.

Air starting valves have been removed from the top of the cylinder head to the side in order to make a simpler installation and to facilitate the removal of the cylinder head for inspection. Individual forged steel



SHOP VIEW OF THE ENGINE SHOWING THE FUEL OIL PUMP, THE GOVERNOR LUBRICATOR AND AIR STARTING PIPING

cylinder pumps are used and the engine is under control of a governor which regulates the length of the stroke of the fuel oil plunger. Reciprocating fuel and lubricating oil supply pumps are used and the engine designed as a full Diesel is used without electric torches or hot bulbs for starting.

Filtrator System for Boiler Cleaning

IN THIS system, the Filtrator is a cast-iron cylinder with outer flange rings and containing an inner perforated cylinder which is filled with flaxseed. The lid is held on by a yoke and clamp screws. Steam is piped direct to the upper end of the filtrator, permeates the flaxseed, extracting from it a mucilage, but no oil, and condenses, producing an emulsion. This descends by gravity and mixes, drop by drop, with the water in the boiler, coating each particle of suspended matter with a thin film so it will not adhere to other particles or to the surfaces of the boiler, as these surfaces also become coated with a protective film.

Particles gradually settle and are carried away with the blow-down water. At intervals, the container is removed from the filtrator and replaced by a spare with a fresh charge of flaxseed. It has been found that the emulsion penetrates cracks in scale already formed, gets between the scale and the metal and loosens the scale, thus cleaning scaled surfaces.

This system is being distributed by the Filtrators Co., 96 Liberty St., New York, N. Y.

POOR METHODS and poor materials give but one result—dissatisfaction.

News Notes

ARRANGEMENTS are being made by the Fuels Division of the American Society of Mechanical Engineers for a National Fuels Meeting to be held in St. Louis, October 10 to 13, for considering questions in regard to the conservation and economical use of fuels. A most attractive preliminary program has been prepared and further information will be given later.

BANCROFT GHERARDI, Vice-President and Chief Engineer, American Telephone and Telegraph Co., New York, was elected President of the American Institute of Electrical Engineers at the annual business meeting held in the Engineering Societies Bldg., New York, Friday, May 20. President-elect Gherardi was born in San Francisco, Calif., April 6, 1873. After receiving his degree of M. M. E. from Cornell University in 1894, he entered the employ of the New York Telephone Co., 1895 and 4 yr. later was made Traffic Engineer. After serving in various important capacities in the Engineering Department of the company, he was finally elected Vice-President and Chief Engineer of the American Telephone & Telegraph Co. in April, 1920. He was Vice-President of the A. I. E. E. in 1908-10, has served on various committees and is president of the United Engineering Society and member of the Engineering Foundation Board.

ANNOUNCEMENT has just been made of the appointment of the following to be members of the executive committee of the recently organized New Jersey Electric Association: for one year, E. C. Peebles, manager, Rockland Electric Co., and W. C. Buell, president, Millville Electric Light Co.; for two years, M. A. Bovlan, general manager, Jersey Central Power & Light Co., H. T. Pritchard, vice-president, Eastern New Jersey Power Co.; for three years, J. H. Drake, vice-president, Central Jersey Power & Light Co. and E. L. White, general manager, New Jersey Power & Light Co.

STEPHENS-ADAMSON MFG. CO., Aurora, Ill., announces that on June 1 it will place in operation a complete manufacturing plant at Belleville, Ontario. G. A. Freeman, for 15 yr. associated with the main organization at Aurora, will be in charge of the new plant. From the branch factory will be supplied the entire S-A conveying machinery line for the Canadian trade, in addition to a general export business to foreign markets.

ANDREWS-BRADSHAW CO., Pittsburgh, Pa., announces the addition to its personnel of R. N. Robertson as Chief Engineer and A. L. Menzin as Director of Research. Mr. Robertson, a Cornell man, class of 1905, comes from the American Smelting & Refining Co., after twenty years of service with that organization. Mr. Menzin, a graduate of the University of California, class of 1907, has been Consulting Engineer with the Edge Moor Iron Co. and Chief Engineer of the Tracy Engineering Co.

AT A REGULAR MEETING of the Board of Directors of the American Brown Boveri Electric Corp., New York, held on April 29, it was announced that the corporation has executed a contract with the United States Navy to complete scout cruiser Salt Lake City and the machinery for the scout cruiser Pensacola for approximately $11,000,000. In addition the corporation has been awarded a contract for an additional cruiser. With the announced withdrawal of Wm. Cramp & Sons from the shipbuilding industry, American Brown Boveri has been able to engage the services of John F. Metten, previously Vice-President and Chief Engineer of Cramps, as Vice-President in charge of Marine Engineering. It is announced also that Moloney Electric Co., one of the subsidiaries of American Brown Boveri Electric Corp., will shortly occupy its new plant in St. Louis.

UNDERLYING COMPANIES of Cramp-Morris Industrials, Inc., which was formed recently to take over the six subsidiaries of the William Cramp & Sons Ship and Engine Building Co. when the parent company decided to discontinue shipbuilding, have been extending their operations in the manufacture of Diesel engines, castings, hydraulic and other machinery. Several important contracts are being completed and new orders have just been booked.

Catalog Notes

THE CARBORUNDUM CO., Niagara Falls, N. Y., in an illustrated 8-page bulletin describes the Carbofrax recuperator designed for application to all types of industrial furnaces.

THE CROUSE-HINDS CO., Syracuse, N. Y., in catalog No. 2100 illustrates and describes its new line of Obround condulets. These are constructed so that coverings and wiring devices are complete units. They are designed for easy installation and no screws project inward to injure the conductors. A wedge-nut fastener securely holds the covering or wiring device.

TAYLOR SPIRAL RIVETED PRESSURE PIPE is completely described and illustrated in an attractive 78-page bulletin No. 28 just issued by American Spiral Pipe Works, Chicago, Ill. The illustrations show the application of this pipe in hydro-electric work, mining and water supply projects, as well as with sand pumping equipment and for many other services. Details of pipe and joints are given as well as tables of prices, dimensions, also data for calculating pipe sizes.

"PROGRESS IN NUT TURNING" is the title of a well-illustrated bulletin published by Snap-On Wrench Co., Chicago, Ill. Wrenches described in this bulletin are socket wrenches supplied with various types of handles and ratchets adapted to tightening nuts in many inaccessible places, such as on line shafting, machinery, inaccessible valves, boiler hand hole plates and the like. The bulletin shows how these sets are assembled in various combinations of handles and sockets, together with methods of using them.

THE RESEARCH DEPARTMENT, National Lime Association, has prepared a manual of "Methods of Analysis of Limestone, Quicklime and Hydrated Lime," divided into three sections: (1) Method of Sampling and Care of Samples; (2) Methods for Routine Analysis; and (3) Methods for Particularly Refined and Detailed Analysis. This is intended primarily as a laboratory manual for use in the laboratories of the Association and also for those manufacturers and users who must keep informed of the chemical composition of their product or raw material.